Series II, Volume 1 June 21, 1956 Number 5

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

1956 SUMMER MEETING IN THE WEST

AT THE

UNIVERSITY OF OREGON, EUGENE, OREGON

June 21, 22, and 23

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1956 Summer Meeting in the West at the University of Oregon, Eugene, Oregon, June 21, 22, and 23, 1956

THE **1956 summer meeting on the Pacific Coast of the American Physical Society** will be held at the University of Oregon in Eugene, Oregon, on Thursday, Friday, and Saturday, **June 21, 22, and 23.** It is just 26 years (June 19–21, 1930) since we last met in Eugene. The attendance was not recorded then, but there were 25 abstracts at the meeting.

This program consists of 59 contributed papers and 16 invited papers. It is therefore possible to avoid parallel sessions completely except for Friday morning when Session D will parallel Session C for approximately one hour. This means that we have the desirable feature of no competition between programs. To accomplish this, however, it has been necessary to lengthen some of the sessions far beyond the normal limits that have been observed heretofore. This procedure is experimental in nature for this program, and it will be interesting to see if the advantages do indeed outweigh the objections.

As a result of the compression of the program into seven sessions, the entire meeting will be held in the Science Building, and the **registration desk** will be located in the lobby of the Science Building on the University of Oregon campus. As usual, the registration fee will be $1. At the desk, tickets for the **banquet** will be sold for $2.50 per plate until *1:00 P.M. Thursday.* The banquet of the Society will be held on Friday evening at 7:00 o'clock in the Erb Memorial Union on the campus. The principal speaker will be Professor A. C. Helmholz on "The Responsibility of Physicists as Educators." Professor R. T. Ellickson will preside. A **cocktail hour** will be held in the Colonnade Room of the Eugene Hotel from 5:30 until 6:30 P.M. on June 22, preceding the banquet. Since no tickets for the banquet can be sold after 1:00 P.M. on Thursday, June 21, members who expect to arrive in Eugene after that hour should order their banquet tickets by mail, in advance, by sending $2.50 per person to Dr. B. Crasemann, Physics Department, University of Oregon, Eugene, Oregon.

The **ladies' programme** has been arranged by the wives of the members of the Physics Department in Eugene. On Thursday, at 3:00 P.M., there will be a conducted tour of the University Museum of Art, including the Warner Collection of Oriental Art. The tour will be followed by a tea served in the patio of the museum.

For the best methods of **travel** the reader is referred to the preliminary announcement of the 1956 summer meeting in the West in the Bulletin of the American Physical Society, Series II, Volume 1, page 159. The **hotel accommodations** are repeated here as follows: Hotels—Eugene Hotel, $5 to $6 single, $8 double, $9 twin; Osborn Hotel, $4 to $4.50 single, $5 to $6 double, $6.50 to $7 twin. A list of motels in the area has been compiled and is available either at the office of the Local Secretary or from Dr. B. Crasemann, Chairman of the Local Committee.

Post deadline, ten-minute papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received not later than Monday, June 11, at the office of the Local Secretary for the Pacific Coast (the address below). These papers will be presented following Session D if the Chairman rules that the time is sufficient.

For the **calendar of meetings and deadlines** for the season 1956–1957, see the New Haven bulletin. Mention is here made that the next meeting on the Pacific Coast will be the one to be held **at Monterey, California,** on December **27–29, the deadline being October 19, 1956,** at the address below.

Errata pertaining to abstracts in this issue will be published in a subsequent issue of the Bulletin if received not later than Monday, June 25, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Do not send in the abstracts marked with corrections. Write out the corrections in the form "Instead of . . . read. . . ." Add nothing.

W. A. NIERENBERG,
Local Secretary for the Pacific Coast
University of California
Berkeley 4, California

Wanted

The American Physical Society would like to buy the following copies of *The Physical Review* for 1955: January 1, January 15, April 1, and July 1. Payment of $1.50 per copy will be made. Copies should be sent to Mr. Wallace Waterfall, American Institute of Physics, 57 East 55th Street, New York 22, New York.

EPITOME OF THE 1956 EUGENE MEETING

(Personal names are those of invited speakers.)

Thursday Morning

10:00 A. Dyke, Ch'en. Electron Physics and Spectroscopy. Science 123.

Thursday Afternoon

2:00 B. Boehm, Schmidt, Stephens, Farwell. Nuclear Structure. Science 123.

Friday Morning

9:00 C. Brolley. Neutron and Reactor Physics. Science 123.

10:00 D. Sound and General Physics. Science 16.

Friday Afternoon

1:30 E. Ravenhall, Gow, Bradner, McIntyre. High-Energy Physics. Science 123.

Friday Evening

8:00 Banquet of the American Physical Society. Helmholz. Erb Memorial Union

Saturday Morning

9:30 F. Jeffries, Arnold, Smaller. Nuclear Energy Levels. Science 123.

Saturday Afternoon

1:30 G. Goldman, Brattain. Solid-State Physics. Science 123.

PROGRAMME

THURSDAY MORNING AT 10:00

123 Science Building

(MARK GUREVITCH, presiding)

Invited Papers

A1. Recent Developments in Field and *T-F* Emission. W. P. DYKE, *Linfield College, McMinnville, Oregon.* (30 min.)

A2. Van der Waals Bands of Alkali Metals in the Presence of Foreign Particles. S. Y. CH'EN, *University of Oregon.* (30 min.)

Electron Physics and Spectroscopy

A3. Investigation of the Bragg-Gray Principle with Fluorescent X-Rays.* H. V. LARSON, *General Electric Company.*—The Bragg-Gray principle was investigated in the energy range from 8.16 to 34.3 kev for Cu and Al walled Bragg-Gray chambers. Fluorescent x-rays provided nearly monoenergetic photons. The pressure (P) of the air inside the Bragg-Gray chamber was varied and the corresponding current per gram of air (J_Z) was measured. These values were divided by the current per gram of air (J_{air}) as measured with a free-air ionization chamber. A plot of J_Z/J_{air} *vs* P was extrapolated to zero pressure. The Bragg-Gray chamber theory predicts that the limiting value of J_Z/J_{air} is proportional to the ratio of the mass energy absorption coefficients ($\mu_Z{}^a/\mu_{air}{}^a$) and inversely proportional to the ratio of the stopping powers $(dE/\rho dx)_Z/(dE/\rho dx)_{air}$. The experimental values of J_Z/J_{air} agreed within experimental error with the values of J_Z/J_{air} that were computed from the known values of the absorption coefficients and stopping powers at 8.16, 16.1, and 23.7 kev for both the Cu and Al walled Bragg-Gray chambers. At 34.3 kev there is a 15 to 18% difference between the experimental and theoretical values of J_Z/J_{air}.

* This paper describes in part work done under contract W-31-109-Eng-52 between the General Electric Company and the U. S. Atomic Energy Commission.

A4. Scattering of Electrons by Metal Foils: Fluorescent Radiation.* RICHARD A. FERRELL, *University of Maryland.*—The treatment already given to the problem of excitation of plasma oscillations by fast electrons passing through metal foils[1] is extended to a calculation of the flourescent radiation which one should expect to be given off by the plasma oscillations. Since in a bulk sample of metal these oscillations are purely longitudinal and do not radiate, it is essential to take into account the foil thickness effects discussed by Gabor.[2] The fraction of the collective oscillations de-excited by radiation is generally very small and depends on the lifetime of the oscillations, or equivalently, on the sharpness of the characteristic energy loss line. Aluminum is hence one of the most favorable cases and should emit radiation at 845 A. The possibility of employing the Bohm-Pines theory[3] to estimate the lifetime of the oscillations and thereby the absolute intensity of radiation will be discussed.

* Research supported by the Office of Naval Research.
[1] R. A. Ferrell, Phys. Rev. **101**, 554 (1956).
[2] D. Gabor, Phil. Mag. **1**, 1 (1956).
[3] D. Bohm and Pines, Phys. Rev. **92**, 609 (1953).

A5. Limitations on the Production of a Ring Current of High-Speed Particles. S. H. NEDDERMEYER, *University of Washington.*—The limitations on the production of a steady high-current beam of particles are examined under highly artificial simplifying assumptions, including especially the neglect of injection difficulties, and the assumption of a constant beam section. Under the assumption that particles can be injected continuously into a close bundle of orbits in an external magnetic field, a balance between the injection current and the losses of particles arising from the various processes of energy degradation and scattering in the presence of the self-magnetic field of the beam leads to a qualitative relationship between the injection current and the steady current in the beam. Three different systems are considered: (a) a beam of counter-moving positrons and electrons, (b) electrons with a quasi-stationary neutralizing cloud of protons, and (c) protons with a neutralizing cloud of electrons. For systems (a) and (b) the multiple scattering and orbital radiation are the dominating processes, and for (c) the energy losses to the electrons. The results suggest that it might be possible to produce steady currents of relativistic particles of the order of thousands of amperes; however, the injection difficulties seem to be of a fundamental character.

A6. Radiation Effects on Plasma Oscillations.* J. E. DRUMMOND, *Sylvania Electric Products Inc.*—The following results have been obtained from an analysis of plasma oscillations in a static magnetic field allowing for the electromagnetic vector potential: (1) A differential equation has been derived for the time dependence of a perturbation in the charge density of a low-temperature plasma. This contains terms arising from beam driving as well as radiation damping. (2) Radio-frequency electron currents are found to flow along the axis of the static magnetic field even though the electric field strength is entirely transverse to this axis. (3) Power can be radiated or absorbed at certain frequencies for which a phase resonance occurs between electric field strength and current density. For low-temperature plasmas, these resonance frequencies are close to integral multiples of the electron cyclotron frequency. This agrees with Nelson's interpretation[1] of the "gaps" deduced by Gross[2] in the spectrum of traveling plasma waves. An upper limit to the resonance frequency spectrum is found to result from phase disrupting collisions and a Landau-type diffusion damping. Possible applications of this theory will be mentioned.

* This work was performed under Signal Corps Contract No. DA-36-039-sc-31435.
[1] D. Nelson, Ph.D. thesis, Oregon State College, 1954.
[2] E. P. Gross, Phys. Rev. **82**, 232 (1951).

A7. Pressure Broadening of the Violet Triplet of Mn Produced by He and A.† ROBERT B. BENNETT AND SHANG YI CH'EN, *University of Oregon* (introduced by R. T. Ellickson).—An absorption chamber which could stand both high pressures and high temperature was designed to make possible the observation of the absorption lines of low vapor pressure metals

under high pressures of foreign gases. Preliminary data on the broadening and shift of Mn λ4030 triplet under various pressures of He and A up to 150 atmos were presented. The temperature of the absorption chamber under high pressures could be raised to 1400°C.

† Supported by the National Science Foundation.

A8. Orbit-Orbit Interaction. H. D. GREYBER,* *University of Pennsylvania.*—The fact that a correction $\alpha L(L+1)$ added to the Slater first-order perturbation theory considerably improves the agreement between calculated and observed energies in the analysis of complex spectra has been variously interpreted as a polarization effect[1] and as orbit-orbit interaction. The interpretation of the effect as orbit-orbit interaction was first suggested by Layzer[2] and, independently suggested in 1951, by Greyber.[3] Some values of α for $3d$ and $4d$ electrons were calculated from analysis of certain complex spectra. A crude Bohr orbit type estimate of the size of the orbit-orbit interaction relative to the spin-orbit interaction was made, and a simple theoretical correction to this estimate was shown to improve the agreement between the estimated and calculated values of α in four out of five cases.

* Now at the University of California Radiation Laboratory, Livermore, California.
[1] R. E. Trees, Phys. Rev. **84**, 1089 (1951).
[2] D. Layzer, Ph.D. thesis, Harvard University, 1950.
[3] H. Greyber, Ph.D. thesis, University of Pennsylvania, 1953.

A9. Fine Structure Self-Broadening of Atomic Lines.* MAKOTO TAKEO,† *Department of Physics, University of Oregon, Eugene, Oregon.*—Foley calculated the relative half-widths of doublet components in the principal series of alkali metals under J representation. But, since the resonance interaction is quite long range, it is obvious that the perturbation energy is easily more than the doublet spacing and may destroy the J representation. Actually, the perturbation energy is more than one-tenth of the spacing, even at the distance of separation (10 A) for resonance lines. A perturbation calculation, taking into consideration the doublet spacing, shows that an intermixing between unperturbed sublevels in $^2P_{\frac{1}{2}}$ and $^2P_{\frac{3}{2}}$ with the same magnetic quantum number takes place and the energy levels split into sublevels, each of which is doubly degenerate (symmetric and antisymmetric). At low pressure, the splitting is nearly the same for the two level groups corresponding to $^2P_{\frac{1}{2}}$ and $^2P_{\frac{3}{2}}$, while, with increasing pressure, the splitting of the original level, $^2P_{\frac{1}{2}}$, becomes larger than the other group. Hence, the ratio of half-widths for doublet components seems to be a function of pressure instead of a constant. The relative transition probabilities between these sublevels and ground states with electric dipole radiation decreases rather rapidly with the decreasing distance of separation.

* Supported by the Natioanl Science Foundation, NSF-G1872.
† On leave from Department of Physics, Defense Academy, Japan.

THURSDAY AFTERNOON AT 2:00

123 Science Building

(S. T. STEPHENSON, presiding)

Invited Papers

B1. Collective and Intrinsic Modes of Excitation in Deformed Nuclei. F. BOEHM, *California Institute of Technology.* (30 min.)

B2. Beta- and Gamma-Ray Spectroscopy of the Light Elements. F. H. SCHMIDT, *University of Washington.* (30 min.)

B3. Odd Parity States in Heavy Even-Even Nuclei. F. S. STEPHENS, JR., *University of California Radiation Laboratory.* (30 min.)

B4. Alpha-Particle Scattering and Nuclear Shell Structure. G. W. FARWELL, *University of Washington.* (30 min.)

Nuclear Structure

B5. Neutron and Proton Levels in a Velocity-Dependent Potential.* A. A. ROSS, R. D. LAWSON, AND HANS MARK, *University of California, Berkeley.*—The neutron and proton level sequences in a diffuse, velocity dependent potential[1,2] have been investigated. The proper neutron level sequences and binding energies can be obtained by choosing $V_0=69$ Mev, $\alpha=1.16\times10^{13}$ cm^{-1}, $r_0=1.3\times10^{-13}$ cm, $\lambda=33$, and $M_{eff}\sim M/2$ at the center of the nucleus. Using the same α and r_0 for protons (with a Coulomb potential corresponding to a uniform charge distribution but neglecting Pauli principle correlations) it is found that the well depth V_0, must be increased roughly 13 Mev in heavy nuclei (Pb^{208}) in order to give the correct binding energy for the last proton. The surface thickness of the potential corresponding to $\alpha=1.16\times10^{13}$ cm^{-1} is about 3.8×10^{-13} cm. The surface thickness of the resulting charge distribution estimated by a Fermi-Thomas method is 2.3×10^{-13} cm which is in good agreement with experiment.

* Supported in part by the Office of Ordnance Research, U. S. Army.
[1] M. H. Johnson and E. Teller, Phys. Rev. **98**, 983 (1955).
[2] Mark, Lawson and Ross, Bull. Am. Phys. Soc. Ser. II, **1**, 16 (1956).

B6. *D-D* Reaction Cross Sections.* L. ROSEN, T. M. PUTNUM, AND J. E. BROLLEY, JR., *University of California Los Alamos Scientific Laboratory.*—The angular distributions of the He^3 particles and protons from the $D(d,n)He^3$ and $D(d,p)T$

reactions are being investigated as a function of deuteron energy. The source of deuterons is the Los Alamos variable-energy cyclotron. The detectors are nuclear emulsions exposed in the Los Alamos multiplate camera. Identification of the He^3 particles is accomplished by utilizing *E*1 emulsions processed so as to surpress the tracks of singly charged ions. Range and ionization criteria permit the rapid identification of more than 90% of the He^3 particles. In the remaining cases comparison is made with deuteron track endings, grain and blob counting being invoked as a last resort. To date experiments have been completed at 8.2, 10.4, and 12.2 Mev. The results, based on 80 000 tracks for each of the proton runs and 30 000 tracks for each of the He^3 runs may be represented by the Legendre polynomial

$$\sigma(\phi_{CM})(\text{mb/steradian}) = a_0P_0 + a_2P_2 + \cdots + a_{10}P_{10}$$

for which the constants will be given.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

B7. p-d Scattering at 7.85 Mev.* JOHN E. BROLLEY, JR., T. M. PUTNUM, AND L. ROSEN, *University of California Los Alamos Scientific Laboratory.*—The new Los Alamos variable energy cyclotron has been used as a source of protons of 7.85±0.075 Mev. An ion optical system conducted the cyclotron beam to the Los Alamos nuclear multiplate camera which was filled with high-purity deuterium. Final precise collimation of the proton beam was achieved in the camera. The total charge passing through the camera was measured by a slideback current integrator that maintained a Faraday cup at essentially ground potential. The scattered particles, both protons and deuterons, were counted on 100-micron *C*2 plates. These plates had extra plasticizer to permit predesiccation in a good vacuum prior to loading in the camera. The range 15 to 160°c.m. was covered with overlapping proton and deuteron counting. Angular resolution was ±0.1°. Average estimated probable errors were $2\frac{1}{4}$% for protons and $3\frac{1}{4}$% for deuterons. Coulomb-nuclear interference is manifest around 40°c.m. unattended by any clearly defined minimum. A comparison with elastic scattering theories extant will be made. Evidence for breakup of the deuteron is insubstantial.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

B8. Note on the Nuclear Collective Monopole Oscillations. M. DANOS, *National Bureau of Standards.*—The hydrodynamic model of collective nuclear oscillations predicts besides the dipole resonance a monopole resonance at an energy $E_M = 2.16E_D$ (E_D=energy of the dipole resonance). Inclusion of the compressibility of nuclear matter will change the energy ratio insignificantly. All other possible multipole modes are strongly influenced by their coupling to the nuclear surface. The monopole resonance should be present in heavy nuclei. In light nuclei the damping could destroy the resonance since here the wavelength of the oscillation is already short compared to the interparticle distance. This resonance could be observed only by inelastic high-energy electron scattering. The cross section for this process has been calculated by Schiff. The experimental investigation of the monopole mode could give the following information: (1) Differentiate between Goldhaber and Teller's third model and the hydrodynamic model (the former does not allow for a monopole mode). (2) Test of the details of the hydrodynamic model, since it predicts both the location of the resonance and the magnitude of the matrix element.

B9. Improved Method of Gamma-Ray Calorimetry.* IRA T. MYERS, *General Electric Company.*—The total energy emission of a 2-curie gamma-ray source was measured, using modified isothermal calorimetry. The time constant of the system was necessarily large, due to the large amount of lead required to absorb the 1.17- and 1.33-Mev gamma rays emitted by the cobalt-60 source used. Slow changes, especially in the thermal resistance between the calorimeter and constant temperature bath, limited the accuracy obtainable with conventional methods. From a study of the errors involved, a modification was evolved which used the apparatus of conventional isothermal calorimetry, but which had a significantly smaller total error. The entire curve of temperature *vs* time was utilized, instead of only the equilibrium value as t approached infinity. Ratios of the temperature difference between the bath and the calorimeter with the source only heating the calorimeter, and with the source plus electrical heating, were plotted as a function of the time after the calorimeter passed through the bath temperature. A minimum in the error in the ratios exists at about $\tau/3$, where τ is the characteristic time of the calorimeter.

* This paper describes in part work conducted under contract W-31-109-Eng-52 between the General Electric Company and the U. S. Atomic Energy Commission.

B10. Scattering of 14-Mev Neutrons from Carbon. D. E. WOOD* AND J. B. SINGLETARY, *Northwestern University.*—The energy distribution of 14-Mev neutrons scattered from carbon has been measured at angles from 30° to 150° by the nuclear emulsion method. Plates were exposed by the P–10 group at Los Alamos using a collimator and shield described previously.[1] Analysis of neutrons above 1 Mev shows resolved groups corresponding to elastic scattering and excitation of the 4.4 and 9.6-Mev levels in C^{12}*. Backgrounds were taken without scatterer at each angle; 4700 tracks were analyzed including backgrounds. Elastic scattering shows no significant peak (except in the forward direction), but does become flat from 60° to 120°. Scattering to the 4.4-Mev level shows a peak in the forward direction, a lower peak in the backward direction, and a minimum at 90°. Scattering to the 9.6-Mev level shows a peak in the forward direction, but statistics are too poor to allow further analysis. Cross-section values and angular distribution curves will be presented. Multiple scattering corrections have not been made.

* Now at General Electric Company, Richland, Washington.
[1] L. Rosen and L. Stewart, Phys. Rev. **99**, 1052 (1955).

B11. Shell-Model Pairing Energies.* R. D. LAWSON AND A. A. ROSS, *University of California, Berkeley.*—Assuming a delta-function interaction between particles, pairing energies have been calculated for nucleons bound in various states of the static diffuse potential,[1] $V(r) = -V_0/1+\exp\alpha(r-a)$. The strength of the interaction was arbitrarily chosen to fit the difference in the (γ, n) thresholds in Pb^{207} and Pb^{208} (0.633 Mev). With this assumption it follows that the $1h_{11/2}$ level near the 82 shell can lie approximately as much as 0.9 Mev above the $3s_{\frac{1}{2}}$ level in the average potential. The pairing energy will then still be sufficient to give the observed ground-state spins and parities of nuclei in this region. In order to retain the correct ground state of Bi^{209} ($1h_{9/2}$ proton) the surface layer on the potential may be increased by approximately 0.25×10^{-13} cm (which changes α from 1.45 to 1.34 $\times10^{13}$ cm^{-1}) if the spin-orbit energy is decreased from 39.5 to approximately 36.5 times the Thomas term. This leads to a surface thickness of the proton charge distribution in gold of approximately 2.1×10^{-13} cm, which is to be compared with[2] $2.4\pm0.3\times10^{-13}$ cm.

* This research supported in part by the Office of Ordnance Research, U. S. Army.
[1] Lawson, Ross and Mark, Bull Am. Phys. Soc., Ser. II, 1, 17 (1956).
[2] Hahn, Ravenhall and Hofstadter, Phys. Rev. **101**, 1131 (1956).

FRIDAY MORNING AT 9:00

123 Science Building

(J. L. POWELL, presiding)

Invited Paper

C1. Angular Distribution of Fission Fragments. JOHN E. BROLLEY, JR., *University of California Los Alamos Scientific Laboratory.* (30 min.)

Neutron and Reactor Physics

C2. Resonance Capture of Neutrons by Uranium Cylinders.* MONTE V. DAVIS, *Oregon State College.*—Reactivity measurements have been conducted in the Hanford Test Pile to determine the effective capture cross section of U^{238}, in the form of cylinders, for neutrons in the energy range from approximately 0.5 to 10^5 electron volts. The measured reactivity changes associated with altering the configuration of cadmium-covered uranium cylinders are related to the resonance capture through the expression for the resonance escape probability. The effects other than the resonance capture are removed by the cladding of cadmium over the uranium, and by surrounding the uranium with graphite moderator to eliminate those neutrons having sufficient energy to cause fissions of U^{238} nuclei. Experimental corrections account for the effects attributed to the U^{235} fissions from resonant neutron capture. The results are expressed in terms of the effective resonance integral and are compared to values predicted by assuming that the resonance capture may be decomposed into volume and surface effects.[1]

* Part of a dissertation presented to Oregon State College (May, 1956). The research was performed under the auspices of the U. S. Atomic Energy Commission at the Hanford Operation of the General Electric Company.
[1] E. P. Wigner *et al.*, J. Appl. Phys. **26**, 260 (1955).

C3. Total Neutron Cross Section of Tm from 0.038 ev to 1.56 ev.* J. E. EVANS AND E. G. JOKI, *Phillips Petroleum Company.*—Measurements of the total cross section of thulium from 0.038 ev to 1.56 ev have been made with the Materials Testing Reactor crystal spectrometer. The sample consisted of twelve cylindrical pellets, 0.422 cm in diameter by 0.160 cm, having a total weight of 2.414 grams of metallic thulium. A matched pair of borated plastic collimating sample holders were used for these measurements. The data from 0.04 ev to 0.7 ev can be described by the expression $\sigma(E)=6.5+20.1\ E_{ev}^{-\frac{1}{2}}$ (barns). The extrapolated value for the total cross section at 0.0253 ev is 134 ± 3 barns.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

C4. Total Neutron Cross Sections and Resonance Parameters in Cd.* F. B. SIMPSON AND R. G. FLUHARTY, *Phillips Petroleum Company.*—The total cross sections for cadmium have been determined from 14.5 ev to 11 kev. These data were taken with 0.05–0.07 μsec/meter resolution using the Materials Testing Reactor fast chopper. In this region resonances were observed at 18.0, 27.4, 63.6, 66.8, 85.4, 86.4, 90.0, 99.8, 108.7, 120.1, 139, 164, 192, 215, 225, 233, 259, 305, 387, 436, 500, and 650 ev. Resonances at 27.4, 86.4, and 99.8 ev were assigned to Cd^{111}, and those at 18.0, 63.6, 85.4, and 108.7 ev to Cd^{113}. The isotopic assignments have been made by using a sample enriched in Cd^{111} and another sample depleted in Cd^{113} (these samples were used to resolve the 85.4 and 86.4 ev resonances). Breit-Wigner parameters have been obtained up to 121 ev, and a value of $\bar{\Gamma}_n^0/D$ assigned to each isotope. The value of $\bar{\Gamma}_n^0/D$ determined from the first three levels in Cd^{111} is $(0.19\pm0.08)\times10^{-4}$, and the value determined from the first five levels in Cd^{113} is $(0.25\pm0.08)\times10^{-4}$. These values of $\bar{\Gamma}_n^0/D$ are based on a $\Gamma\gamma$ of 113 mv which was obtained from the 0.178-ev Cd^{113} level. Those $\Gamma\gamma$'s which could be obtained by thick-thin sample measurements have quite large errors but are not in disagreement with the assumed value.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

C5. Fission Cross Section of U^{233} from 0.035 to 5.3 ev.* L. G. MILLER AND J. E. EVANS, *Phillips Petroleum Company.*—The Materials Testing Reactor crystal spectrometer has been used to measure the fission cross section of U^{233} from 0.035 to 5.3 ev. The over-all instrument resolution was 0.9 μsec/meter or 2.5% in energy at 1 ev. Preliminary values for the full widths at half-maximum, corrected for Doppler broadening and instrument resolution, for the two resonances at 1.80 ± 0.02 ev and 2.30 ± 0.02 ev are 0.36 ev and 0.17 ev, respectively. Other resonances were observed at 3.6 ev and 4.7 ev. Since appreciable instrument resolution corrections were needed for the resonances above 2 ev, the measurements are being repeated with an instrument resolution of about 0.1 μsec/meter.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

C6. High-Resolution Soller Slit Collimator for Use with the MTR Neutron Crystal Spectrometer.* E. G. JOKI AND J. E. EVANS, *Phillips Petroleum Company.*—The resolution of the Materials Testing Reactor (MTR) crystal spectrometer has been improved to better than 0.1 μsec/meter by use of a Soller slit collimator of novel construction. The value of such collimators in studying low-energy neutron resonances has recently been demonstrated by Sailor *et al.*[1] The MTR collimator was made by stretching 0.001 nickel foil lengthwise. Coatings of polyethylene approximately 1.5 microns thick on the foils surfaces reduce total reflection. Two collimators with 30 and 40 parallel channels $48\times2.5\times0.010$ inches (angular divergence, 0.7 minute of arc) have been constructed. Using one collimator at the reactor face and a second one on the spectrometer arm rocking curves having full widths at half-maximum of 0.5 minute have been obtained at 1 ev with the 221 planes of a calcite monochromating crystal.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Sailor, Foote, Landon, and Wood, Rev. Sci. Instr. **27**, 26 (1956).

C7. High-Resolution Fast Chopper Detector Using BF_3 Counters.* O. D. SIMPSON, R. G. FLUHARTY, AND L. W. MCCLELLAN, *Phillips Petroleum Company.*—Time delays between signals from banks of BF_3 counters[1] are used in the Materials Testing Reactor fast chopper to effectively reduce the counter length from 10 in. to 2 in. For the 45-meter flight path, this improves the instrument resolution from 0.13 to 0.05 μsec/meter for neutron energies greater than 10 ev without reducing the counter efficiency. An effective counter length of 2 in. in the neutron beam is normally used, and 1 in. (the

counter diameter) can be used when needed. When the 1-in. effective length is used, the detector does not affect the instrument resolution at energies normally studied with the chopper. Five counter banks of 16 counters each are connected in parallel with separate delays for four banks. The signals from the five banks are mixed and fed through a common amplifier after being delayed and amplified in separate preamplifiers. Pulse-height distributions, gamma discrimination techniques, and other features will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] O. D. Simpson and R. G. Fluharty, U. S. Atomic Energy Commission Report, IDO-16110 (1954).

C8. Lattice Testing Reactor.* D. J. DONAHUE, D. D. LANNING, AND W. A. HORNING,† *General Electric Company.*—A critical assembly has been constructed to investigate the possibility of measuring the nuclear parameters of various types of reactors by critical experiments. This critical assembly is a seven-foot cube of graphite with a large cavity, about 2×2×3 ft, located at its center. Sufficient enriched uranium to make the assembly critical is distributed around this central cavity in such a manner that the neutron flux distribution in the cavity is radially symmetric and can be made flat in the longitudinal direction. The control rods are so constructed and distributed that they do not appreciably disturb this flux distribution. One end of the assembly with dimensions 2×7×7 ft rests on a movable cart and can be driven a distance of six feet away from the reactor proper. When this portion is in the removed position, the central cavity is accessible, and can be filled with several cubic feet of the particular multiplying medium which is to be investigated. Some details of the design will be presented, together with experimental data showing the neutron flux distribution through the test cavity.

* Under the auspices of the U. S. Atomic Energy Commission.
† Now at the Ramo-Wooldridge Corporation.

C9. Measurement of k_∞ Using the Lattice Testing Reactor (LTR).* D. D. LANNING, D. J. DONAHUE, AND W. J. OZEROFF, *General Electric Company.*—It has been shown that the LTR can be used to measure directly $k_\infty - 1$ for a lattice of unknown properties, where $k_\infty (= \eta \epsilon p f)$ is the infinite multiplication factor of the lattice. First, the reactor is made critical with a central portion of the test core empty. Next the central portion is inserted together with a neutron absorbing material whose absorption properties are known. The amount of absorber, in this case, copper, is adjusted until the critical conditions of the reactor in the filled state and in the empty state are identical. Insertion of the copper changes only the thermal utilization, f. Hence, $\Delta k_\infty / k_\infty = \Delta f / f$. Because for the void $k_\infty = 1$ the Δk_∞ measured by inserting copper is directly $k_\infty - 1$ of the test material. The method of calculating $\Delta f / f$ from the measured mass of copper will be discussed. The results of some experiments will be presented to show that values of k_∞ obtained using only a small piece of lattice in the LTR are applicable to an infinite array of that lattice.

* Under the auspices of the U. S. Atomic Energy Commission.

C10. Prompt Neutron Lifetime in the Hanford Lattice Testing Reactor.* H. W. LEFEVRE AND D. D. LANNING, *General Electric Company.*—A neutron detector with fast response has been used to follow the flux decay in the LTR after a control rod drop. A large sodium iodide crystal surrounded by cadmium detected cadmium neutron capture gamma rays and a photomultiplier converted the scintillations into a voltage drop across a resistor. A plot of this voltage as a function of time as obtained photographically from an oscilloscope gave the variation of neutron flux after the rod drop. By separating the decay into components due to prompt and delayed neutrons, the pile period due to prompt neutrons alone was obtained. The lifetime was determined from this prompt neutron period, the reactivity change, and the delayed neutron fraction. The average prompt neutron lifetime in the LTR as determined by this method was $(1.9 \pm 0.4) \times 10^{-3}$ second. This type of measurement is valid only if the poison insertion time and detector response time are short compared to the prompt neutron period.

* Under the auspices of the U. S. Atomic Energy Commission.

C11. Absorption Cross Section of Copper in a Thermal Neutron Spectrum.* R. A. BENNETT, D. J. DONAHUE, AND D. D. LANNING, *General Electric Company.*—The neutron absorption cross section of copper has been measured relative to that of gold in the thermal spectrum of the Lattice Testing Reactor. Measurements were made on the central axis of a graphite core where the neutron flux was well thermalized and isotropic. Thin $1\frac{3}{4}$-in. diameter foils were used as reactivity samples. The cross section was calculated from reactivity coefficients determined from reactor periods. Corrections for epithermal absorptions were measured, using cadmium covered reactivity samples. Self shielding and flux perturbation corrections were not necessary since the thickness of the gold and copper foils was chosen so that each had nearly equal absorbing properties. The ratio of 2200 m/sec absorption cross sections was found to be $\sigma_0 \mathrm{Au} / \sigma_0 \mathrm{Cu} = 27.50 \pm 0.13$. Using an average of recent values of 99.0 ± 0.2 barns for the gold 2200 m/sec absorption cross section, the copper value was calculated to be 3.60 ± 0.02 barns. Uncertainties are standard errors.

* Under the auspices of the U. S. Atomic Energy Commission.

C12. Resonance Escape Probability in Reactor Lattices. H. NEUMANN, *General Electric Company.**—For a lumped-fuel lattice reactor, the probability that a neutron escape capture during the slowing down process by an isotope with isolated resonances may be shown to be approximately

$$p = \exp\left[-(S/4\xi \Sigma_s V_m) \int du \beta(u) \right],$$

where S = lump surface, ξ = mean logarithmic energy decrement for moderator collisions, Σ_s = moderator macroscopic scattering cross section, V_m = moderator volume per fuel lump, u = neutron lethargy, and $\beta(u)$ = lump blackness (fraction of neutrons entering the lump that are captured). The blackness is a function only of lump materials, temperature, and geometry. Temperature broadened absorption and scattering cross sections, including scattering asymmetry terms, have been generated for eighteen known resonances in U^{238}.[1] Numerical results for p for several graphite-uranium rod lattices will be presented.

* Under auspices of the U. S. Atomic Energy Commission.
[1] Harvey, Hughes, Carter, and Pilcher, Phys. Rev. **99**, 30 (1955).

C13. Slow Neutron Fission Cross Section of Pu^{240}.* B. R. LEONARD, JR., E. J. SEPPI, W. J. FRIESEN, AND E. M. KINDERMAN, *General Electric Company.*—The crystal spectrometer was used to study the slow neutron fissionability of Pu^{240}. A foil of high Pu^{240} content and a Pu^{239} foil were used in a back to back fission chamber. The relative foil weights were determined by fission counting at the 0.3-ev resonance in Pu^{239} where corrections for the Pu^{240} and Pu^{241} contents of the two foils are least important. Two points of high statistical accuracy were taken in the thermal region. The results were 0.97 ± 1.1 barns at 0.075 ev and 0.68 ± 0.93 barn at 0.10 ev. Most of the quoted error is caused by uncertainty in the isotopic content and the fission cross sections of Pu^{239} and Pu^{241}. The energy region around the known 1-ev resonance in the total cross section of Pu^{240} was also investigated. An apparent resonance structure was found with an energy resolution about 2.5 times the level width. The measured peak cross section was 11.5 ± 3 barns corresponding to a true peak value of only about 30 barns. A thermal value of about 0.05 barn

is derived from this resonance which is consistent with our thermal measurements.

* Work performed under coutract with the U. S. Atomic Energy Commission.

C14. Variation of η for Pu^{239} with Slow Neutron Energy.* E. J. SEPPI, B. R. LEONARD, JR., AND W. J. FRIESEN, *General Electric Company.*—Recent measurements[1] of the variation of η, the average number of fast neutrons emitted per slow neutron absorbed, by a direct measurement showed an apparent discrepancy of about 12% with the variation predicted from total and fission cross-section measurements over the energy range 0.025 to 0.3 ev. A variation in ν, the number of fast neutrons per fission, was proposed[1] to account for this apparent discrepancy; however, it has been shown that ν is constant over this energy range.[2] We have measured the variation of η by the direct method and the total and fission cross sections over the energy range 0.03 to 0.5 ev. We find good agreement between the shapes of the variation of η deduced from the two measurements. The rms deviation of the points from a smooth curve fit to both sets of data is 1.0%. The value obtained for η in the 0.3-ev resonance is 18% less than the thermal value (0.03–0.04 ev).

* Work performed under contract with the U. S. Atomic Energy Commission.

[1] Zimmerman, Palevsky, and Hughes, Bull. Am. Phys. Soc., Ser. II, 1, 8 (1956).

[2] Auclair, Landon, and Jacob, Compt. rend. **241**, 1935 (1955); Leonard, Seppi, and Friesen, Bull. Am. Phys. Soc., Ser. II, 1, 8 (1956).

C15. Comparison of the U^{235} Fission Cross Section to the Au^{197} Capture Cross Section.* W. J. FRIESEN, B. R. LEONARD, JR., E. J. SEPPI, AND F. A. WHITE, *General Electric Company.*—The crystal spectrometer has been used to compare the monoenergetic fission cross section of U^{235} with the capture cross section of Au^{197}. A gold foil was irradiated in the 0.10 ev neutron beam directly behind the U^{235} foil whose fission counting rate was observed. The absolute activity of the gold foil was determined by comparison beta counting in a proportional counter with an identical gold foil which was irradiated in a thermal neutron beam and whose absolute activity was determined by beta-gamma coincidence counting. The U^{235} fission cross section at 0.0253 ev is obtained from the previously determined shape of the fission cross section and the assumed Au^{197} capture cross section. Statistical analysis of these measurements shows that the value of the 0.0253-ev fission cross section can be determined to a precision of about 0.7% aside from uncertainties in the gold cross section and the weight of the fission foil. A tentative weight has been assigned to the fission foil by comparison alpha counting against a standard. A preliminary value at 0.0253 ev of 556 barns has been obtained subject to establishing the weight of the fission foil by destructive techniques. A discussion of the uncertainties and the reproducibility of these results will be presented.

* Work performed under contract with the U. S. Atomic Energy Commission.

FRIDAY MORNING AT 10:00

16 Science Building

(W. L. PARKER, presiding)

Sound and General Physics

D1. Correlation Studies of Short Sound Pulses Transmitted in the Sea. C. D. MAUNSELL, J. E. LOKKEN, AND W. N. ENGLISH, *Pacific Naval Laboratory.*—Correlation measurements as previously described[1] have been extended from the study of composite pulses to that of short pulses where the directly transmitted and surface reflected components are separated in time. Typically the directly transmitted pulses show much lower fluctuation than the previous interference pulses. Pulses received by the surface reflection path show intermediate values. For the directly transmitted pulses correlation coefficients between the fluctuations on two hydrophones have a distribution considerably wider than that for the reflected pulses, but this is probably owing to the influence of reading errors. Unlike the case for long pulses the mean correlation between hydrophones separated vertically by several wavelengths is high. In experiments where pulses of 18-kc and 8-kc sound were alternated there was no mean correlation between the fluctuations at the two frequencies although at each frequency the fluctuation at times showed a noticeably periodic pattern. This suggests that the fluctuation on these pulses transmitted by neighboring rays is caused by close-path interference rather than by ray-acoustic effects.

[1] H. L. Grant and R. W. Stewart, Phys. Rev. **92**, 1087(A) (1953); R. W. Stewart and W. N. English, Phys. Rev. **100**, 969(A) (1955).

D2. Turbulent Microstructure in the Ocean. ASHTON M. PATTERSON, *Pacific Naval Laboratory.*—The hot-wire flow meter previously described[1] has been redesigned to improve its frequency response and ruggedness. Spatial "spectra" have been obtained showing scales down to the size of the measuring elements. The influence of an underwater obstacle in altering the spectral distribution, by increasing the portion of the energy in the smaller eddies, has been observed at sea. Recent results will be presented.

[1] R. W. Stewart, Phys. Rev. **96**, 847(A) (1954).

D3. Experimental Factors in a Test of Mintzer's Sound Fluctuation Theory. W. N. ENGLISH, C. D. MAUNSELL, AND J. E. LOKKEN, *Pacific Naval Laboratory.*—Mintzer[1] has developed a theory relating the amount of fluctuation of sound transmitted along a direct path through the ocean to the refractive index variations produced by thermal microstructure. This theory predicted values in reasonable agreement with the experimental data then available. To check the theory we have carried out a three-ship operation with close successive short pulses of 18-kc and 8-kc sound thus enabling the dependence on range and frequency to be studied under the same water conditions. The measured fluctuations on the directly transmitted pulse are smaller than expected from the previously published work. This has also been found in recent work described by Sagar.[2] In our work thermal microstructure measurements were attempted but did not prove suitable to make numerical comparison with the theory. The frequency dependence predicted by the theory was found for the "reflected" ray at the longer range which in this case was strongly refracted downward by a shallow gradient and may not have reached the surface. An experiment to test theory in a region of turbulent rather than temperature microstructure is under consideration.

[1] D. Mintzer, J. Acoust. Soc. Am. **25**, 922 (1953).

[2] F. H. Sagar, J. Acoust. Soc. Am. **27**, 1092 (1955).

D4. Magnus Effect at Very High Reynolds Numbers. HOWARD R. KELLY, *U. S. Naval Ordnance Test Station.*—It is shown from the results of a current experimental program with spinning cylinders in a subsonic wind tunnel that the negative Magnus force reported by Lafay[1] and the positive force measured by Betz[2] and others fit logically into a systematic variation with Reynolds number. The effective range of test Reynolds numbers has been greatly extended, with the role of this parameter more evident than ever before. Using the most recent results of this experimental program, a qualitative explanation of the systematic variation is given in terms of the critical Reynolds number. The possibility of achieving lift coefficients approaching the theoretical limit of 4π is discussed.

[1] Lafay, Rev. Mecanique **30**, 431 (1912).
[2] Betz, Z. Ver. deut. Ing. (1925); (NACA TM-310).

D5. Effects of Time-Varying Impulses on a Ballistic Galvanometer. DAVID WOODBRIDGE AND W. R. VARNER, *Oregon State College.*—The complete galvanometer equation, except for coil capacitance, has been solved and confirmed by experiment. The displacement of the galvanometer coil was measured as a function of time and compared with the instantaneous input current for various pulse shapes. The lag time of a ballistic galvanometer coil depends upon the peak voltage and time location of this peak. For short steep pulses the lag is negligible for practical measurements. With a galvanometer having a 16-sec period the deflection is a maximum, for all types of impulses, if the duration of the entire pulse passed through the galvanometer is between 0.5 and 0.7 sec, or about 1/30 period.

D6. Mass Spectrometer Based on the Lateral Velocity Acquired by Ions in Passing through a Transverse Magnetic Field.* GERTRUDE FLEMING REMPFER, *Fisk University.*—When an ion with an initial velocity v passes through a transverse magnetic field, it acquires a lateral velocity

$$v_x = (HL/c)(q/m). \tag{1}$$

L is the length of the field in the direction of the initial velocity, and the other quantities have their usual significance. Ions of different q/m can be distinguished by measuring the lateral stopping potential corresponding to v_x, or the time of flight for a given lateral displacement. We are constructing a simple mass spectrometer based on this theory. Since (1) does not contain v, an instrument operating on this principle would have the advantage that the resolution is not impaired by fluctuations in accelerating voltage, or distribution in energy at the source.

* Supported by a grant from the Research Corporation.

D7. Linear Approximation Useful in Multiple Dielectric-Layer Interference Optics. ROBERT WEIR REMPFER, *Fisk University* (introduced by Nelson Fuson).—The usual relations for calculating optical characteristics of multilayer interference systems are nonlinear, taking the form of bilinear recursion relations. Many important features of such optical systems in the case of dielectric layers are surprisingly well brought out qualitatively by retaining only terms of first order, i.e., by replacing all relations by linear ones.

FRIDAY AFTERNOON AT 1:30

123 Science Building

(R. B. BRODE, presiding)

Invited Papers

E1. Electron Excitation of Nuclei. D. G. RAVENHALL, *Stanford University.* (30 min.)

E2. The Development and Operation of Liquid Hydrogen Bubble Chambers. J. D. GOW, *University of California Radiation Laboratory.* (30 min.)

E3. High-Energy Physics with Hydrogen Bubble Chambers. HUGH BRADNER, *University of California Radiation Laboratory.* (30 min.)

E4. Electron Scattering by the Deuteron. JOHN A. MCINTYRE, *Stanford University.* (30 min.)

High-Energy Physics

E5. Rapid Cycling Liquid Propane Bubble Chamber.* R. A. BURNSTEIN, R. M. KALBACH, AND J. J. LORD, *University of Washington.*—A cylindrical metal and glass bubble chamber of about ¼ of a liter sensitive volume has been rapidly cycled.[1] A 5-in. diam nylon-cord rubber diaphragm formed the seal for the chamber and communicated pressure changes to the propane. The diaphragm was directly in contact with an external, mechanically driven piston. The piston was part of a rebuilt refrigerator compressor and was cycled at rates of from 15 to 30 cps.[2] In a typical experiment, a gamma-ray source was placed near the bubble chamber and a stroboscopic light was flashed slightly out of phase with the compressor. Thus it was possible to photograph the characteristics of an individual cycle in great detail. Simultaneously, the pressure variations were recorded by a pressure sensing device directly in contact with the liquid. The results of these experiments and current investigations will be reported.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Many of the parts used in this experiment were furnished by Professor J. Steinberger.
[2] A 60-cycle clean chamber was constructed at the University of Chicago. (Private communication from Professor R. Hildebrand.)

E6. Multiple Coulomb Scattering of 6.2-Bev Protons in Photographic Emulsions.* J. J. LORD, DAVID B. CHANG, AND FRED W. FISCHER, *University of Washington.*—Multiple scattering measurements of Berkeley 6.2-Bev protons have been made in G-5 emulsions 600 microns thick. The scattering data has been made and analyzed by the Fowler method in terms of cell lengths of 500, 1000, 2000, and 5000 microns in order to investigate noise or spurious scattering errors due to

emulsion dislocations. The tracks selected were quite parallel to the plane of the emulsion and the cotangent of the dip angle was always greater than 50. Three different precision stages constructed in our shop were used and in all cases the stage, reading, temperature, and grain noises were insignificant compared to the emulsion dislocation noise. The mean values of the second differences calculated for the dislocation noise were 0.38, 0.86, and 1.97 microns for cell lengths of 1000, 2000, and 5000 microns, respectively. These data are based on 1130, 490, and 56 cells, respectively. These observations are in general agreement with the cosmic-ray observations summarized by Lohrman *et al.*

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E7. Question of Interdependence of Cosmic-Ray Stars in Nuclear Emulsions.* R. E. SKINNER,† *Atomics International Division of North American Aviation, Inc.*—Investigations of the "close pair" effect in cosmic-ray stars show a disparity in the reported results and the theoretical expressions given. Here the theoretical considerations underlying the investigations are evolved into a consistent model. Equations, including those of Li and of Brown and Masket,[1] for the expected number of "close pairs" with separation $\Re$ and orientation angle Θ, where $r_1 \leq \Re \leq r_2$ and $\vartheta_1 \leq \Theta \leq \vartheta_2$, on a plate are derived assuming a "uniform" distribution and independence of the stars. A test is devised to test the postulate of uniform distribution of the stars independently of that of independence. Experimental problems are investigated and tests related for systematic errors obtained. Various mechanisms of interdependence are discussed and corresponding expressions for the expected number of pairs given. An examination of the literature to date leads to the conclusion that evidence for the existence of the effect is not conclusive, but that the theory evolved here may enable definite conclusions to be reached from further experimentation.

* This paper based in part on a thesis submitted by the author in partial fulfillment of the requirement for the Degree of Bachelor of Arts, Reed College.
† Work done in part while a National Science Foundation predoctoral fellow at the California Institute of Technology.
[1] T. T. Li, Phil. Mag. **41**, 1152 (1950); F. B. Brown and A. V. Masket, Phys. Rev. **88**, 1204 (1953).

E8. Yield of π^0 Photomesons as a Function of Atomic Number.* JOHN D. ANDERSON, ROBERT W. KENNEY, AND CHARLES A. MCDONALD, *University of California Radiation Laboratory.*—With a single gamma counter[1] at 135° to the incident photon beam, the relative yields of π^0 mesons per nucleon were observed for Be, C, CF_2, Al, Ti, Fe, Cu, Ag, and Pb. The yields were observed as a function of the maximum energy of the bremsstrahlung beam from the 340-Mev Berkeley Synchrotron. The maximum beam energy and the bremsstrahlung spectrum were monitored with a three-channel pair spectrometer. The root-mean-square counting errors for all energies were from 2% to 10%. The yield per nucleon at $E_{max} = 340$, 250, 200, and 175 Mev goes as $A^{-\frac{1}{3}}$. If an optical model is assumed, the mean free path for absorption of π^0 mesons in nuclear matter is between 1 and 3 r_0 where $r_0 = 1.4 \times 10^{-13}$ cm.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] G. Cocconi and A. Silverman, Phys. Rev. **88**, 1230 (1952).

E9. Measurement of Electron Pair Cross Sections at Several Bev.* JOHN M. BRABANT, ROBERT W. KENNEY, AND ROGER WALLACE, *University of California Radiation Laboratory.*—Photons of several Bev energy arise from neutral pion decay in the forward direction in bevatron targets bombarded by the circulating 6.2-Bev proton beam. These photons have been used to determine electron pair-production cross sections in aluminum and lead. A conventional good-geometry absorption technique was employed, using a large lead glass Čerenkov photon spectrometer (of the type used in the measurement of antiproton annihilation energies[1]) as the detector in coincidence with a scintillation counter photon telescope. The spectrometer response to neutrons contained in the neutral particle beam, but not eliminated by the photon telescope, was corrected for by a subtraction technique involving the differential absorption of photons by lead placed ahead of the sweeping magnet and collimating system. The experimental apparatus and the data will be discussed and preliminary results for the 2.5-Bev cross sections will be given.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] J. M. Brabant *et al.*, Phys. Rev. **101**, 498 (1956); (to be published).

E10. Some Properties of Anomalous θ^0 Mesons.* JOHN A. KADYK, G. H. TRILLING, R. B. LEIGHTON, AND C. D. ANDERSON, *California Institute of Technology.*—Concerning the identity of the so-called "anomalous θ^0" mesons, two possibilities have so far received attention: That *all* θ_{anom}^0 are purely (1) neutral τ mesons, or (2) alternate decay modes of ordinary θ^0 mesons into, for example, $\pi + \mu + \nu$. Possibility (1) appears to be ruled out by the observation of apparent Q values substantially greater than 80 Mev. We believe that possibility (2) can be ruled out also upon the basis of a number of observed differences with respect to θ^0 mesons. From a sample of sixteen θ_{anom}^0, we have found the following: (a) The maximum likelihood mean life of the θ_{anom}^0 is apparently somewhat greater than that of θ^0. (b) The origins of θ_{anom}^0 are, on the average, farther from the cloud chamber than are those of θ^0, indicating again longer mean life for θ_{anom}^0. (c) The momenta of θ_{anom}^0, allowing for the neutral decay particle, are considerably lower than of θ^0. (d) The only θ_{anom}^0 which have been seen in association with other strange particles have occurred with a normal θ^0, a probable K^+, and a V^+, respectively. Our ordinary θ^0 have been observed in association with Λ^0, V^-, and Ξ^-. (e) Out of about 600 normal θ^0, none has been seen moving upward from their point of production, whereas two out of sixteen θ_{anom}^0 were traveling upward.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission. Reproduction in whole or in part is permitted for any purpose of the U. S. Government.

E11. Relativistic Increase of Ionization in Helium.* T. L. AGGSON, W. B. FRETTER, L. F. HANSEN, AND R. G. KEPLER, *University of California, Berkeley.*—The relative probable ionization in helium has been measured for $\beta\gamma$ from 4 to about 200 with μ mesons and for $\beta\gamma$ from 60 to about 2000 with electrons. The measurements were made by counting drops along the tracks formed in a cloud chamber to determine the ionization and by measuring the radius of curvature to determine the momentum and thus $\beta\gamma$. The identity of μ mesons was established by a counter system requiring a traversal of lead. Electron showers were obtained by another counter system and the electron identities were inferred from the electronic appearance of the showers. The counter system was set up so that two μ-meson pictures were taken followed by one electron shower and this cycle repeated continuously. Therefore the μ-meson and electron ionization curves were obtained under the same cloud-chamber conditions. Approximately 120 μ mesons and the same number of electrons distributed fairly equally over their full range were counted. Preliminary results agree with the theory by Budini. Complete results will be reported.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E12. Extraordinary Cosmic-Ray Burst of February 23, 1956.* AUREL GOODWIN, JR., AND ROBERT B. BRODE, *University of California, Berkeley.*—On February 23, 1956, at about 0348 UT a cosmic-ray burst was observed in which the neutron

intensity increased by 600%, the unshielded Geiger counter telescope by 58% and the Geiger-counter telescope with a 20-cm lead filter by 38%. This cosmic-ray burst was recorded by many other laboratories and the results of these observations are compared with the Berkeley measurements.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

E13. Nucleon Total Cross Sections for 4.2-Bev Negative Pions.* H. A. BOSTICK, B. J. MOYER, AND N. F. WIKNER, *University of California Radiation Laboratory.*—A magnetically analyzed and focused beam of 4.2-Bev negative pions produced by bombarding a Be target with 6.2-Bev protons at the bevatron has been utilized to determine the total cross sections σ_H and σ_D by measuring attenuation differences in good geometry of CD_2, CH_2, C, D_2O, H_2O with a 32-ft counter telescope consisting of four scintillation counters operated in coincidence. With the bevatron operating at 10^{10} protons per pulse a pion flux of 20 per cm² per pulse was detected. Preliminary calculations have yielded the results: $\sigma_D = 50.8 \pm 3.7$ mb, $\sigma_H = 28.2 \pm 3.5$ mb, $\sigma_N = 23.2 \pm 3.2$ mb for the target series $CD_2 - CH_2 - C$ and $\sigma_N = 22.7 \pm 3.3$ mb from the $D_2O - H_2O$ difference. Correction has been made for π-μ decay which can occur along the 60-ft pion trajectory from production target to attenuator. At most, this correction amounts to 3.4% of the beam intensity and reduces the apparent transmission of each attenuator. Effects of Coulomb scattering are insignificant and do not enter due to the subtraction technique employed. Good agreement of values σ_H measured from varied attenuator lengths reduces the likelihood of systematic errors due to geometry.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

E14. Nuclear Cross Sections for 4.2-Bev Negative Pions.* N. F. WIKNER, H. A. BOSTICK, AND B. J. MOYER, *University of California Radiation Laboratory.*—In order to measure the total and reaction cross sections of several nuclei simultaneous transmission measurements in good and poor geometry have been performed at the Berkeley bevatron. The pions were produced by bombarding a Be target with 6.2-Bev protons. These pions are analyzed by the bevatron's magnetic field before leaving the quadrant vacuum tank thin window. The pions then passed through two strong focusing quadrupoles and were further analyzed before entering the counter telescope. The pion beam incident on the attenuator was defined by two 1-in. diam counters 12 ft apart. Poor and good geometry counters (5-in. diam and 4-in. diam, respectively) were located 8 ft and 20 ft from the end of the defining telescope yielding a total telescope length of 32 ft. The cross sections of the following four elements were measured and preliminary calculations give the following values for the total and reaction cross sections—σ_{total} (mb, ±3%): Be, 220; C, 316; Al, 674; Cu, 1618; σ_{reaction} (mb, ±3%): Be, 158; C, 218; Al, 396; Cu, 794. Corrections have been made for muon contamination and Coulomb scattering losses.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

FRIDAY EVENING AT 8:00

Erb Memorial Union

(R. T. ELLICKSON, presiding)

Banquet of the American Physical Society

After-Dinner Speech: A. C. Helmholz, "The Responsibility of Physicists as Educators"

SATURDAY MORNING AT 9:30

123 Science Building

(C. SHARP COOK, presiding)

Invited Papers

F1. Nuclear Moments of Radioactive Nuclei by Paramagnetic Resonance. C. D. JEFFRIES, *University of California.* (30 min.)

F2. High Resolution of Some Proton Magnetic Resonance Spectra. J. ARNOLD, *Stanford University.* (30 min.)

F3. Spin Resonance Detection of Irradiation Effects in Solids. B. SMALLER, *Argonne National Laboratory.* (30 min.)

Nuclear Energy Levels

F4. Spin of Rubidium Isotopes of Mass 81, 82, 83, 84.* R. SUNDERLAND, J. C. HUBBS, W. A. NIERENBERG, AND H. B. SILSBEE, *University of California Radiation Laboratory.*—The nuclear angular momenta of four neutron-deficient isotopes of rubidium have been determined by the atomic beam magnetic resonance method. The isotopes, with half-lives between 4.7 hr and 80 days are produced in quantities of 10^{13} to 10^{14} atoms by alpha-spallation reactions in the Berkeley 60-in. cyclotron. Detection of the beam is accomplished by allowing a neutral beam to fall on a sulfur surface at room temperature; the sur-

face then being removed from the apparatus and counted with low-background, high-efficiency scintillation counters which accept K x-rays accompanying K capture and internal conversion. Experimental results are for rubidium-81, $I=3/2$, rubidium-82, $I=5$, rubidium-83, $I=5/2$, and rubidium-84, $I=2$. Each isotope was further identified by a measurement of the half-life on the spin resonance peak.

* This research supported in part by the Office of Naval Research and the U. S. Atomic Energy Commission.

F5. The Spin of Rubidium-81.* H. A. SHUGART, J. C. HUBBS, E. LIPWORTH, W. A. NIERENBERG, AND H. B. SILSBEE, *University of California Radiation Laboratory.*—The spin of a new 30-min isomeric state of rubidium-81 recently found by W. Doggett,[1] has been measured by the atomic beam magnetic resonance method and found to be 9/2. Primary identification came from the measurement of the half-life of the peak resonance button since the principal problem is the detection of this isotope above the background of the 4.7-hr rubidium-81 and 6.3-hr rubidium-82 isotopes that are made in the same bombardment and are present during the run.

* This research was supported in part by the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] W. Doggett, Ph.D. thesis, University of California, 1956 (unpublished).

F6. Disintegration of Ge^{68}.† BERND CRASEMANN, D. E. REHFUSS,* AND H. T. EASTERDAY, *University of Oregon.*—The isotope Ge^{68} has been prepared by the bombardment of zinc with 37-Mev alpha particles and separated chemically. The half-life of Ge^{68} is 275 ± 20 days, as determined by comparison with a Co^{60} standard over 10 months. The positron spectrum was measured with a thick lens magnetic spectrometer. Positron groups from Ga^{68} have maximum energies of 1.94 and 0.92 Mev and relative intensities of 1 and 0.04, respectively; no positrons from Ge^{68} were observed above 0.3 Mev. The scintillation spectrum shows annihilation radiation and a 1.02-Mev gamma ray from Ga^{68}. Comparison of areas under these two peaks, corrected for crystal efficiency, indicates that there are 14.4 ± 1.7 positrons per 1 Mev quantum. Within the probable error, this result is compatible with the decay of Ge^{68} by electron capture alone.

† Supported by the National Science Foundation and by the Graduate School of the University of Oregon.
* National Science Foundation Predoctoral Fellow.

F7. K Capture/β^+ Ratios in Co^{56} and Co^{58}. C. SHARP COOK AND F. M. TOMNOVEC, *U. S. Naval Radiological Defense Laboratory.*—The ratio of orbital electron capture to positron emission has been measured for Co^{56} by comparing the intensity of the annihilation radiation to the 0.845-Mev gamma ray, which is assumed to follow all Co^{56} disintegrations. This value is $\epsilon/\beta^+=4.4$. A similar experiment for Co^{58} in which the annihilation radiation is compared to the 0.805-Mev gamma ray gives a ratio $\epsilon/\beta^+=5.9$. The existence of a 1.67-Mev gamma ray following the decay of Co^{58} having an intensity 0.005 relative to the 0.805-Mev gamma ray has been verified.[1,2]

[1] Robinson and Fink, Bull. Am. Phys. Soc., Ser. II, 1, 40 (1956).
[2] Rossi, Frauenfelder, Levine, and Singer, Bull. Am. Phys. Soc., Ser. II, 1, 163 (1956).

F8. Radionuclide K^{37}.† C. R. SUN AND BYRON T. WRIGHT, *University of California, Los Angeles.*—Since the discovery[1,2] of the 0.95-sec activity of K^{38}, the assignment to K^{37} of the activity previously reported[3,4] has been in doubt. We have bombarded natural calcium with 12.8 Mev protons and observed a 1.2-sec activity. The end point was found to be 5.1 Mev with a double-channel magnetic spectrometer.[5] We suggest that this activity be assigned to K^{37} formed by the reaction $Ca^{40}(p,\alpha)K^{37}$ from the following considerations: (1) the bombarding energy is well below the thresholds of $Ca^{40}(p,n)Sc^{40}$, and $Ca^{40}(p,pn)Ca^{39}$; (2) other activities are very unlikely from the considerations of the yield; and (3) the half-life, end point, and ft value are within the expected range. The final results with probable errors will be presented.

† This work was partially supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] P. Stähelin, Helv. Phys. Acta **26**, 691 (1953).
[2] R. M. Kline and D. J. Zaffarano, Phys. Rev. **96**, 1620 (1954).
[3] R. V. Langmuir, Phys. Rev. **74**, 1559(A) (1948).
[4] F. I. Boley and D. J. Zaffarano, Phys. Rev. **84**, 1059(L) (1951).
[5] C. R. Sun and B. T. Wright, Phys. Rev. **100**, 1793(A) (1955).

F9. Elastic Scattering of Protons at 12 Mev.* H. C. SHAW, H. E. CONZETT, R. J. SLOBODRIAN,† AND R. G. SUMMERS-GILL,‡ *University of California Radiation Laboratory.*—By use of 12-Mev protons from the Crocker Laboratory 60-in. cyclotron, absolute differential cross sections have been measured for elastic scattering from Be, C, Mg, Al, Fe, Ni, Cu, Zn, Rh, Ag, Cd, In, Sn, Ta, Pt, Au, Pb, and Bi. The experimental apparatus and procedure have been described previously.[1] Generally, data were taken at 5° intervals from 7° to 90° and in 10° steps from 90° to 160°. The distributions show interference effects similar to those at 17 Mev.[2] Even for Bi (barrier energy 15 Mev) deviations from Rutherford scattering are observed. Cross sections for large-angle scattering from light elements are greater than Rutherford, while those for heavy elements are less. In spite of detailed search (Fe to Zn, Ag to Sn, and natural Pb, Pb^{208}, and Bi) for special behavior due to shell structure, only apparently smooth variations with A were found. The data have been submitted for analysis using the diffuse-surface optical model.[3]

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† Investigador Auxiliar of Comision Nacional de la Energia Atomica of Argentina visiting the Radiation Laboratory, Berkeley.
‡ National Research Council of Canada Special Scholar.
[1] R. E. Ellis and L. Schecter, Phys. Rev. **101**, 636 (1956).
[2] I. E. Dayton and G. Schrank, Phys. Rev. **101**, 1358 (1956).
[3] Melkanoff, Moszkowski, Nodvik, and Saxon, Phys. Rev. **101**, 507 (1956).

F10. Single-Particle States for a Spheroidal Nucleus.* MARVIN RICH, *University of California Radiation Laboratory.*—In discussions of the relation between shell structure and nuclear deformation the view is taken that each nucleon occupies an eigenstate of a spheroidal potential characterized by energy $E_i=\langle T_i+V_i\rangle$. Energies, E_i, are adjusted to fit the empirical filling order of nucleons. Assuming two body forces, the contribution of each nucleon to the total energy is $\epsilon_i=\langle T_i+\frac{1}{2}V_i\rangle$. To obtain ground-state deformations, energies ϵ_i are summed for the first N nucleons of each type as prescribed by the level diagram, E_i, and the total minimized as a function of deformation. It is often possible, however, to find still lower total energies by summing the ϵ_i for different sets of nucleons, since total energies are governed by the ϵ_i not E_i. A computation of eigenstates for a spheroidal potential has been completed assuming that the E_i should fit the emperical level ordering. A similar calculation is underway assuming the ϵ_i should fit the emperical ordering, and a comparison of wave functions will be made to see which scheme produces better agreement with empirical data. The calculation is similar to that of Nilsson except for replacement of his l^2 term by a truncation of the oscillator bottom.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

F11. The 1.8-Mev Level of Be^9.† R. G. SUMMERS-GILL.* *University of California Radiation Laboratory.*—The nearness of the neutron threshold to the recently reported 1.8-Mev level of Be^9 has cast doubt[1] on the existence of the latter. If neutrons in reactions of the type $Be^9(x,nx')Be^8$ are liberated via heavy-particle stripping, consideration of the three-body kinematics shows that the scattered charged particles will have a spectrum peaked at an energy closely corresponding to a Q value of ~1.8 Mev in Be^9. The exact "Q value" is, however, a function of the angle of observation of the scattered particles and of the

bombarding energy. Calculations of this and of the width of the peak will be presented. Measurements on the 1.8-Mev peak in inelastic proton scattering at 12 Mev[2] show just such a variation with angle. Other experiments (including Li^7+He^3 and $B^{11}+d$) will be analyzed from a similar point of view. It is conjectured that the level at 4.8 Mev in Be^9 may also be a ghost as a result of a similar mechanism in which the Be^8 is excited to its 2.9-Mev state.

† This work was done under the auspices of the U. S. Atomic Energy Commission.
* National Research Council of Canada Special Scholar.
[1] Rasmussen, Miller, Sampson, and Gupta, Phys. Rev. **100**, 851 (1955).
[2] R. G. Summers-Gill, Phys. Rev. **100**, 1795(A) (1955).

SATURDAY AFTERNOON AT 1:30

123 Science Building

(E. A. YUNKER, presiding)

Invited Papers

G1. Magnetic Analysis of Imperfections in Alloys and Metal Oxides. J. E. GOLDMAN, *Scientific Laboratory, Ford Motor Company.* (30 min.)

G2. Distribution of Energies and Cross Sections of Surface Traps on Germanium. W. H. BRATTAIN, *Bell Telephone Laboratories.* (30 min.)

Solid-State Physics

G3. Diffusion of Helium in Thorium and Uranium.* ALAN ANDREW, LYLE E. GLASGOW, AND CLIFTON R. DAVIDSON, *Atomics International.*—Helium diffusion in thorium and uranium has been investigated in thin foils. The difficulty of preparing a "solution" of helium in a metal has been overcome by the use of different energy beams of alpha particles from the 60-inch Berkeley cyclotron. The methods of irradiation and subsequent evaluation of the intensity of irradiation have been discussed previously.[1] Following the irradiation the foils were pulsed to a high temperature in a closed apparatus and the evolved helium measured by a Pirani gauge. No evolution of helium was noted for the uranium foil up to 1040°C at which point the foil developed a "hot spot" and destroyed itself. A systematic outgassing of helium was measured in the thorium up to 1450°C. The evolution of gas was found to follow Fick's law with the following constants: E (activation energy) = 38 kcal/mole; Do (diffusion constant) = 10^{-4} to 10^{-3} cm²/sec.

* Work conducted for U. S. Atomic Energy Commission under Contract AT-11-1GEN-8.
[1] Yockey, Andrew, Fillmore, Glasgow, Hunt, and Pepper, Rev. Sci. Instr. **25**, 1011 (1954).

G4. Solid State Surface Free Energy. R. C. SILL, *Stanford Research Institute.*—Solid and liquid state surface free energies (surface tensions), if different, cause a change in the melting temperature of pure materials in thin layer configurations. If h is the thickness of a thin layer, Tm is the bulk (normal) melting temperature, Th is the melting temperature of the thin layer, and k is a constant characteristic of the material which is proportional to the difference in solid and liquid surface free energies, $\sigma_s-\sigma_l$, then a relationship of the form $h(Tm-Th)=k$ can be established from several lines of reasoning. Values of k have been obtained for two fatty acids, stearic and myristic. These values of k suggest ratios of σ_s/σ_l of 3 or 4 to one,[1] which values seem too high to be reasonable. Work is progressing in the attempt to determine whether the measured values of σ_s are too high and to determine the effects of surface contamination. Time lapse photographs of the melting of thin crystals under carefully controlled temperature conditions will be shown.

[1] R. C. Sill, and A. S. Skapski, J. Chem. Phys. **24**, 644 (1956).

G5. Wall Motion and Polarization Reversal in Ferroelectric $KNbO_3$. H. H. WIEDER, *Naval Ordnance Laboratory.*—Single crystals of potassium niobate in the orthorhombic crystal phase were examined optically and electrically. Most crystals are composed of laminated domains having 110* twin planes as described by Wood.[1] Some of the crystals, however, show a twin plane along a 111 axis in analogy to the findings of Forsbergh for orthorhombic $BaTiO_3$. A steady electric field was applied to a crystal having electrodes along a 110 direction with respect to the domain walls. The field was retained until the crystal became saturated. Subsequently, short pulses of opposite polarity were applied to the crystal. It was found that wedge-shaped domains of oppositely directed polarization are nucleated and grow with the applied field in a direction parallel to the original walls. If, however, the electrodes are applied in a perpendicular to the domain walls the latter will move under an applied electric field in such manner as to increase the volume of favorably oriented domains. Domain wall movements and wedge nucleation as described above, can and do occur simultaneously. These results further illustrate the isomorphism between $BaTiO_3$ and $KNbO_3$ described by Triebwasser.

* Referred to cubic axes.
[1] F. A. Wood, Acta Cryst. **4**, 353 (1951).

G6. Ultrasonic Excitation in $NaNO_2$.* R. T. SCHUMACHER AND W. A. ROBINSON, *University of Washington.*—We have observed the effects of ultrasonic excitation of pure quadrupole transitions of Na^{23} nuclei in a single crystal of $NaNO_3$. Pound has shown that the $m=\frac{3}{2}$ to $m=\frac{1}{2}$ and $m=-\frac{1}{2}$ to $m=-\frac{3}{2}$ transitions are split from the center line by static electric field gradients. In our experiment we have observed the magnetic resonance absorption curve of the center line at ν_0 by c.w. techniques while inducing $\Delta m=\pm 2$ transitions between $m=\frac{1}{2}$ and $m=-\frac{3}{2}$ levels by means of an x-cut quartz transducer tuned to $2\nu_0+\delta$, where δ is the splitting of the satellites from the center line. The strength of the center line absorption signal was observed to vary as a function of power to the transducer in a manner essentially in agreement with the theoretical predictions of $m=\frac{1}{2}$, $m=-\frac{1}{2}$ population difference as a function of $m=\frac{1}{2}\leftrightarrow m=-\frac{3}{2}$ transition probability. The experiment also yields information about the phonon relaxation time in $NaNO_2$. Orientation dependence of the center line absorption signal at a single ultrasonic power level will be discussed.

* Research supported in part by the U. S. Air Force.

G7. Infrared Absorption Studies on Barium Titanate and Related Crystals.* JAY T. LAST, *MIT.*—The infrared absorption spectrum of barium titanate has been measured for thin single crystals and for powder samples dispersed in pressed KBr disks. Absorption bands for single-crystal samples occur at 495 cm^{-1} and at *ca* 340 cm^{-1}, arising from normal vibrations of the TiO_3 group. A third vibration, a motion of Ba against the TiO_3 group, occurs below the experimentally accessible range. A frequency of about 225 cm^{-1} is expected for this vibration on the basis of a comparison of the specific heat contributions of the observed bands with the measured low-temperature specific heat. Measurements were made on the 495 cm^{-1} band over a wide temperature range. As the crystal changes from the cubic to the tetragonal, orthorhombic, and rhombohedral structures, band splitting is observed which can be related to the change of crystal symmetry. The spectra of the perovskite titanates, $SrTiO_3$, $PbTiO_3$, and $CaTiO_3$, and the perovskite niobates, $KNbO_3$ and $NaNbO_3$, have been found to be similar in general features to that of $BaTiO_3$. The slight differences in band frequency and structure can be related to differences in unit cell size and symmetry.

* Sponsored by the Office of Naval Research, the Army Signal Corps, and the Air Force.

G8. Effect of Annealing Temperature upon the Internal Friction of Polycrystalline Copper. J. J. BRADY, E. D. FALK, AND M. F. ANDERSON, *Oregon State College.*—The internal friction of polycrystalline copper reeds was studied by means of the resonance method of Jewell.[1] Measurements of Q^{-1} were made on cold-worked reeds which were heated to temperatures ranging from 30°C to 450°C. The internal friction of the annealed reeds reached a minimum value for an annealing temperature of 215°C. Anneals at temperatures above this value left the reed much more strain-amplitude sensitive than anneals at the lower temperature. The internal friction for reeds annealed at 215°C was not changed appreciably by cold work up to 3000 lb/in². Most of the measurements were made at a frequency of 54 cps.

[1] W. R. Jewell, Rev. Sci. Instr. **24**, 5 (1953).

G9. Magnetic Field Dependence of the Hall Effect and Magnetoresistance in Graphite. D. E. SOULE, *National Carbon Company, Union Carbide and Carbon Corporation.*—The Hall effect and magnetoresistance in purified natural graphite single crystals have been measured from 16 to 25 000 gauss at 300°, 77°, and 4.2°K. The Hall coefficient, R, remains negative at large fields (-22 cm^3/coul at 4.2°K and 25 kilogauss) but becomes positive at low fields. This observed behavior is probably due to the existence in graphite of light electrons, light holes and heavy electrons with respective effective masses in the order listed. Only at low temperatures and at very low fields does the light electron produce a detectable Hall voltage. At higher temperatures, the light holes dominate in this low field region while the more numerous heavy electrons are more effective at the high fields. The magnetoresistance ratio, $\Delta\rho/\rho_0$, which previously was found to behave in an anomalous manner, i.e., as $H^{1.8}$, was found to increase as $H^{2.0}$ below about one kilogauss at 300°K. Oscillations analogous to the de Haas-van Alphen effect occur in both R and $\Delta\rho$ with identical periods.

G10. Theory of Magnetoconductivity and Hall Effect in Graphite. J. W. MCCLURE, *National Carbon Research Laboratory and University of Oregon.*—The experimental data of Soule (preceding abstract) have been analyzed in a manner such as used previously for germanium.[1] The components of the magnetoconductivity tensor, which are functions of the magnetic field strength, were found from the experimental data. The parameters in simple theoretical expressions for the conductivity tensor components were chosen so as to reproduce the data. The best fit of the results at 4.2°K indicates the presence of 1.2×10^{17} electrons per cm^3 with a mobility of 1.7×10^6 cm^2 per volt sec, and 0.9×10^{17} holes per cm^3 with a mobility of 1.4×10^7 cm^2 per volt sec. The mobilities estimated from the magnetic field strengths needed to saturate the two kinds of carriers are smaller than those quoted above. A probable reason for the discrepancy is that the simple theoretical formulas used ignore the possibility of a distribution of values for the cyclotron frequency and/or the relaxation time.

[1] Willardson, Harmon, and Beer, Phys. Rev. **96**, 1512 (1954).

G11. Debye Characteristic Temperatures for Noncubic Crystals. D. D. BETTS* AND G. K. HORTON, *University of Alberta.*—The Debye characteristic temperature Θ, for a crystal is proportional I^{-1} where in terms of the velocities, v_i, of elastic waves at 0°K $I=\int f(\theta,\varphi)d\Omega=\int \Sigma_i\{v_i(\theta,\varphi)\}^{-3}d\Omega$. We evaluate the integral I by expanding $f(\theta,\phi)$ in terms of those real spherical harmonics having the symmetry of the secular equation for the v_i, then $I=4\pi a_0$ where a_0, the coefficient of the first harmonic, is expressed in terms of f in certain directions. For five constant hexagonal crystals we have $a_0=[192f_A+57f_B+256f_C+125f_D]/1630$. For six constant tetragonal crystals $a_0=[288f_A+114f_B+512f_C-125f_D+96f_E+375f_F]/1260$ and for six constant hexagonal and rhombohedial crystals $a_0=[1536f_A+456f_B+1024(f_C+f_G)-625(f_D+f_H)+2250f_K]/5040$. The subscripts on f represent directions as follows: A 100, B 001, C 101, D 201, E 110, F $\sqrt{2}$ $\sqrt{2}$ 1, G $10\bar{1}$, H $20\bar{1}$, K 021. Each of the above formulas makes use of all harmonics of degree less than eight and is analogous to Houston's formula as applied by Bhatia and Tauber. Using the above formulas and others of a lower degree of approximation, we have found Θ values for several crystals of each of the above sets of symmetries.

* National Research Council of Canada Post Doctorate Fellow.

G12. Polarization and Electromechanical Activity in Sintered WO_3.* SIDNEY LEVINE, RUDOLPH E. CORWIN, AND HOWARD L. BLOOD, *University of Washington.*—Sintered WO_3 containing small percentages (2–4%) of Ta_2O_5 has been found to exhibit ferroelectric behavior at room temperature. The resistivity and dielectric strength of selected samples was sufficient to permit application of fields as large as 20 kv/cm. Anomalous polarization levels greater than 10 $\mu c/cm^2$ and electromechanical activity corresponding to a polarization direction opposite to that of the applied field has been observed. The reversal in electromechanical activity, first observed in ceramic $BaTiO_3$,[1] following the removal of the polarizing field is felt to represent a metastable state, the stability of which is a function of field exposure (strength and duration). This behavior in WO_3 is attained for field durations short compared to that required for $BaTiO_3$. The coefficient of electrostriction, for the samples investigated, was found to be of the order of 10^{-9} cm/volt. The magnitude of reversed activity for zero external field is comparable with that for field biased electrostriction.

* This work supported by the Bureau of Ordnance, Navy Department, under Contract NOrd 12937.

[1] Blood, Levine, and Roberts, J. Appl. Phys. **27**, 660 (1956).

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Proceedings of the American Physical Society

MINUTES OF THE MEETING OF THE SOUTHEASTERN SECTION HELD AT FISK UNIVERSITY, NASHVILLE, TENNESSEE, MARCH 29, 30, AND 31, 1956

THE twenty-second meeting of the Southeastern Section of the American Physical Society, held at Fisk University, Nashville, Tennessee on March 29, 30, and 31, 1956, was attended by about 250 physicists from the region. The arrangements at Fisk were made by Nelson Fuson and his committee; the program was planned by another committee chaired by Howard Carr. The program of 18 invited and 71 contributed papers appears below. Seven additional papers related to physics teaching are recorded in the *American Journal of Physics*. The dinner address was given by Chancellor A. H. Compton of Washington University, St. Louis and the paper by Dr. H. L. Dodge, president emeritus of Norwich University, was presented at another evening session. During the meeting the section chose the University of Kentucky as the site of its 1957 meeting on April 4, 5, and 6; it also elected the following as its officers for 1956–57: Dixon Callihan, Oak Ridge National Laboratory, chairman; Vincent Parker, Louisiana State University, vice-chairman; Howard Carr, Alabama Polytechnic Institute, secretary; Robert Lagemann, Vanderbilt University, treasurer; and Newton Underwood, North Carolina State College, executive committeeman. Arthur Ruark of Alabama is the retiring chairman.

DIXON CALLIHAN, *Retiring Secretary*
The Southeastern Section
American Physical Society
Oak Ridge, Tennessee

Solid State and X-Rays

(W. M. FAIRBANK presiding)

Invited Papers

A1. Neutron Diffraction Studies of Magnetic Interaction. W. C. KOEHLER, *Oak Ridge National Laboratory*. (30 min.)

A2. Paramagnetic Cooling with High-Field Magnetic Studies of Atomic Interactions. W. E. HENRY, *Naval Research Laboratory*. (30 min.)

Contributed Papers

A3. Crystal Changes of Sulfur. JOHN E. MILLER, NISBET S. KENDRICK, JR., AND G. W. CRAWFORD,* *Clemson College*.—The investigation of the physical processes occurring during the rhombic-monoclinic enantiotropic transition of sulfur by x-ray diffraction necessitates an accurate method of ascertaining sample temperature. The method used from the onset of the experiment was that used by most investigators, namely, to place a thermocouple as close to the sample as possible without interfering with the x-ray beam. This method was found to be completely inadequate for poor conductors such as sulfur. It was found that even though the temperature of the oven and sample holder could be controlled to within $\pm 0.1°C$,[1] neither of these readings could reliably be called the sample temperature at the point of irradiation. To measure this temperature, a thermocouple junction was placed in the sample itself, approximately one millimeter below the sample surface. This thermocouple was the sensing element and was used to control the sample temperature. The high absorptivity of sulfur for x-rays prevented the occurrence of diffraction lines from the thermocouple material. The transformation from one crystalline form to the other was found to occur over a range of about 4°C. As the temperature was elevated in finite increments, a larger relative amount of sulfur was transformed until saturation was reached. It is believed by the authors that an equilibrium is reached at various temperatures and an energy-dependent distribution function is necessary before the transition temperature can be ascertained.

* Now at Texas Petroleum Research Committee, University of Texas.

[1] This equipment was described in a previous paper, Phys. Rev. **99**, 1631 (1955). This project was co-sponsored by the National Science Foundation and the Kress Foundation of Clemson College.

A4. Thickness Vibrations in Long Rods of Barium Titanate. C. V. STEPHENSON, *Sandia Corporation*.—The theory has been developed for thickness vibrations in long thin rods of piezoelectric barium titanate. The theory shows how the thickness coupling coefficient and the piezoelectric constant d_{33} are related to a measurement of the resonant and antiresonant frequencies of the first harmonic. An interesting result of this development is that the antiresonant frequency of this mode of vibration plays a role similar to the resonant frequency in other modes of vibration and is controlled by the physical properties of the material in exactly the same way that these properties control the resonant frequency in other modes. An experiment was devised and the results of this experiment verify this result.

A5. Brillouin Zone Studies. VIII. Thermoelectric Power of Dilute Magnesium Alloys. E. W. KAMMER, E. I. SALKOVITZ, AND A. I. SCHINDLER, *Naval Research Laboratory*.—The present report in this series[1] concerns thermoelectric power measurements at liquid nitrogen temperature on magnesium alloys

containing silver and cadmium, the latter element producing no change in the valence electrons per atom ratio. When the temperature is lowered, the curve for thermoelectric power as a function of atomic percent cadmium impurity simplifies into two straight lines. At liquid nitrogen temperature the slopes of these lines are +0.61 and +0.12 microvolt per °C per atomic percent, the larger value applying to alloys of composition less than 2½% cadmium. Unlike the effect of cadmium additions, the magnitude of the thermoelectric power for all the silver additions increases significantly as the temperature of measurement is lowered; but again the values lie closely along two lines. At 78°K the two slopes are +2.2 and +0.53 microvolts per °C per atomic percent, the larger value applying to concentrations of silver less than ½ atomic percent. The two alloy series can be compared only in the range from ½ to 2½ atomic percent with the presently available compositions. In this interval the ratio of thermoelectric power to atomic percent impurity is approximately the same.

[1] Kammer, Salkovitz, and Schindler, Bull. Am. Phys. Soc. Ser. II, 1, 115 (1956).

A6. Relativistic Corrections to the Cohesive Energies of the Alkali Metals. JOSEPH CALLAWAY, *The University of Miami.*—Recent investigations of relativistic corrections in energy band theory have been almost entirely concerned with spin-orbit coupling. There are other relativistic effects of the same order of magnitude which will alter the effective mass and the cohesive energy. A theory has been developed, based on perturbation theory applied to the second approximation to the Dirac equation, in which energies are calculated to second order in k and to first order in the relativistic corrections. Results will be presented for the change in the ground-state energy and the effective mass. Applications are being made to potassium and cesium. The corrections yield increased binding. This occurs because the probability that a valence electron will be found near the nucleus is, on the average, greater in the solid than in the free atom, owing to the compression of the valence electron into the atomic sphere. The effect is of the order of 1 kcal/mol in potassium and is expected to be of the order of magnitude of the entire cohesive energy in cesium, since there is a Z^4 dependence on atomic number.

A7. *K*-Shell Fluorescence Yields of Ni, Cu, and Zn.† E. T. PATRONIS, JR., C. H. BRADEN, AND L. D. WYLY, *Georgia Institute of Technology.*—In our program of measurements of *K*- and *L*-shell fluorescence yields we have obtained values of ω_K for nickel, copper, and zinc by the direct method. The materials under examination are excited by the x-rays from radioactive Cd^{109} and the fluorescence quanta emitted by the materials are detected by a gas proportional counter. The values obtained are ω_K for nickel $=0.33\pm0.02$, ω_K for copper $=0.39\pm0.02$, and ω_K for zinc $=0.44\pm0.02$, in good agreement with previous measurements employing different techniques.

† This work supported in part by a grant from the National Science Foundation.

A8. Neptunium *L* X-Ray Absorption Spectrum. BETTY LOU DILMORE, GEORGE L. ROGOSA, AND GUENTER SCHWARTZ, *Florida State University.*—The positions of the neptunium *L* x-ray absorption edges have been measured for Np^{237} in a HNO_3 solution.[1] A double-crystal spectrometer was used as monochromator and intensities were determined with a scintillation detector. It is known that the position and shape of an x-ray absorption edge is dependent upon the physical state and chemical form of the element. Since it was impractical to change the chemical form of the neptunium, experiments were undertaken with uranium in different chemical combinations. Uranium in HNO_3 solution and two different uranium oxide foils showed no significant shift of the position of uranium *L* III absorption edge. Choosing a point on the curve which is half-way between the low absorption and the highest absorption at the edge, we find the following values for the energies in kev of the *L* edges of neptunium: *L* I = 22.432, *L* II = 21.594, *L* III = 17.610. These values should be within 5 ev of the critical absorption energies of neptunium. Comparison of the extrapolated values with these measurements shows reasonable agreement.

[1] The neptunium is on loan from the U. S. Atomic Energy Commission.

A9. X-Ray Spectrum from a 100-PKV Therapy Unit.* RICHARD RARIDON AND P. K. S. WANG, *Vanderbilt University.*—In continuation of our x-ray spectrum investigations, measurements were made on the beam from a 100-PKV therapy unit at the Vanderbilt Hospital.[1] This machine employs a water-cooled Machlett tube with a tungsten target and a Villiard circuit. The inherent filtration is equivalent to 0.6 mm of Al. The measurements were carried out with the same scintillation spectrometer which was used for our 50-PKV spectrum determination.[2] The beam was collimated by a small hole through a brass plug, while the detector was shielded with brass and lead. The measured spectrum has two peaks at approximately 32 kv and 53 kv, in fair agreement with Ehrlich's results.[3] The experimental procedure and the x-ray spectrum will be discussed.

* This work was partially supported by a U. S. Atomic Energy Commission sponsored project.
[1] We are indebted to Dr. H. C. Francis and Dr. G. W. Hudson for the availability of the machine.
[2] Wang, Raridon, and Tidwell, Brit. J. Radiol. (to be published); Wang, Raridon, and Crawford, Brit. J. Radiol. (to be published).
[3] Margarete Ehrlich, J. Research Natl. Bur. Standards **54**, 107 (1955).

A10. Melting Point of Crystalline Argon. JOHN H. HENKEL, *University of Georgia* (introduced by E. H. Dixon).—The equation of state of liquid argon is developed under the assumption that every argon atom moves in a potential field because of a static spacial distribution of all the other argon atoms. Some short-range ordering is introduced by assuming that twelve nearest neighbors are distributed spherically on a spherical shell concentric with the mean position of the atom under consideration. The rest of the atoms are distributed uniformly outside another concentric shell. The equation of state is developed along lines previously discussed for solid argon. The melting point of crystalline argon is defined as the temperature at which the free energy of crystalline argon under zero pressure is equal to free energy of liquid argon under zero pressure.

Spectroscopy

(ALVIN H. NIELSEN presiding)

B1. Visual Determination of Relative Intensities of Spectral Lines. E. SCOTT BARR, *The University of Alabama.*—Comparison of spectral line intensities is commonly accomplished by densitometer evaluations of photographed spectra, or by direct use of a calibrated photoelectric cell. The present procedure has been found adequately accurate and appreciably simpler for situations where it can be used. The equipment utilized is a Martens-type photometer and a spectrometer fitted with a

shutter eyepiece (all of Bausch and Lomb manufacture), designed primarily for transmission curve measurements of filters. White light is sent along one optical path through the photometer, and the radiation under study along the other. Each spectral line is compared in turn with the corresponding small section of the continuous spectrum isolated by the shutter eyepiece. By use of an optical pyrometer to measure the temperature of the filament of the white light source, the relative energy throughout the visible spectrum is determined. The observed spectral line intensities are then suitably corrected to give relative intensities. The sensitivity of the human eye limits the range over which this method can be used. Each intensity comparison is, however, made at a single wavelength, and has been found consistent. Thanks are due to Mr. Charles C. Cason for experimental assistance.

B2. Construction of a Vacuum Grating Infrared Spectrograph.* JOHN A. HERNDON, ALVIN H. NIELSEN, AND H. RAY MINK, *The University of Tennessee.*—A grating spectrograph for the infrared, designed to operate in a vacuum, is currently being constructed in the physics shop of The University of Tennessee. The instrument will employ a modified Pfund optical system of about f:5.6 with a 12-in. diameter, 48-in. focal length, mirrors; and will accommodate gratings of about 6 in.×8 in. It is expected that lines separated between 0.05 cm^{-1} and 0.08 cm^{-1} will be resolved. The instrument is housed in a large horizontal cylindrical vacuum tank having a volume of about 3.8 cubic meters, and will be operated at less than 0.1 mm of mercury pressure. Slides will be shown of the appearance and present state of the instrument and details of its design and construction will be given.

* Supported by Office of Ordnance Research, U. S. Army.

B3. Grating Investigation of the Infrared Spectrum of HCOF and DCOF.† ROY F. STRATTON AND ALVIN H. NIELSEN, *The University of Tennessee.*—The infrared spectrum of HCOF and DCOF recently examined prismatically[1] is being re-examined with a grating spectrometer. These molecules are accidentally nearly symmetric tops having asymmetry parameter K of -0.97 and -0.93, respectively. Because the dipole moment has components along both the least and intermediate axes of inertia the absorption regions appear with widely spaced Q branches superposed on bands with PQR structure. At the time of this preliminary report it may be said that the FCO bending vibration for both molecules at 663 cm^{-1} and 658 cm^{-1}, respectively, have been resolved for the coarse Q structure. These spacings are about 5.4 cm^{-1} and 3.7 cm^{-1}, respectively. The $\Delta J=\pm 1$ structure has not been resolved. The $\Delta J=\pm 1$ spacings for 2ν (CO stretch) for HCOF at 3638 cm^{-1}, for 2ν (CF stretch) in DCOF at 2138 cm^{-1}, and for the planar CH bending frequency of DCOF at 968 cm^{-1} have been resolved and are found to be about 0.8 cm^{-1}, 0.6 cm^{-1}, and 0.7 cm^{-1}, respectively. Slides of the scanned regions will be shown.

† Supported by the Office of Ordnance Research, U. S. Army.
[1] Morgan, Staats, and Goldstein, J. Chem. Phys. (to be published).

B4. Force Constants in Deuteromethanes. JOSEPH W. STRALEY, AND ROBERT E. HILLER, *University of North Carolina.*—The determination of force constants in the deuteromethanes is being carried out as part of a program of measuring and interpreting the intensities of infrared absorption bands in these compounds. Approximate values of all constants involved are available in the literature of the halogenated methanes which yield zeroth-order approximations to the F-matrix elements. To improve on the accuracy of these constants an iteration procedure is being carried out using frequency data from molecules of the type CH_nD_{4-n}. Letting the zeroth-order F-matrix elements be represented by F_{ij}^0 we may write $F_{ij}=F_{ij}^0+\Delta_{ij}$. Introducing this expression into the secular determinant and neglecting terms higher than the first order in the Δ_{ij} leads to a set of linear equations in Δ_{ij}. The solutions of the equations yield improved values of F_{ij}^0 and the process is repeated. Tentative values of all force constants in methane will be presented.

B5. A Normal Coordinate Analysis of $COCl_2$. ROBERT J. LOVELL* AND ERNEST A. JONES, *Vanderbilt University.*—A re-evaluation of the force constants for phosgene seemed desirable when new microwave work yielded molecular parameters that differed significantly from those derived from earlier electron diffraction measurements. For this reason, a normal coordinate analysis utilizing these new parameters was undertaken. This analysis shows that the valence force potential function which had been assumed for this molecule is inadequate and should be generalized to include a term describing an interaction between the C−Cl bond and Cl−C−Cl angle. The force constant governing this interaction was found to have a value of about 5×10^{-4} dyne/cm. Complete results will be presented in the paper.

* Now at the University of Tennessee.

B6. Generalized Expression for Spectral Slit Width.* R. EDWIN WORLEY,† *Fisk University.*—The Fraunhofer diffraction images of finite spectrograph slits are reviewed,[1,2] and attention is called to a persistent misconception regarding their width.[3] The response of instruments that employ exit slits, notably infrared spectrometers, depends jointly on the width of this slit and on the diffraction image of the entrance slit. This feature of joint dependence underlies the generalized expression for *spectral slit width* commonly cited in the literature.[4] A consideration of the theoretical basis of this expression leads to a more specific formulation, and points up the slight discrepancies between certain alternative definitions of spectral slit width. Means of calculating this quantity from instrument specifications, or with the supplementary aid of a calibration curve, will be given elsewhere.

* Supported in part by the National Cancer Institute.
† On leave of absence from the Department of Physics, University of Nevada.
[1] See E. C. C. Baly, *Spectroscopy* (1929), third edition, Vol. 1, Ch. IX.
[2] R. A. Sawyer, *Experimental Spectroscopy* (1951), second edition, pp. 111–114. References to original paper are listed.
[3] Thus, the statement beginning 15th line from bottom on p. 281 in Baly[1] is incorrect.
[4] Van Zandt Williams, Rev. Sci. Instr. **19**, 151, 153 (1948).

B7. Shifts and Shapes of HF Vibration Lines with Foreign Gases. D. F. SMITH, *Union Carbide Nuclear Company.*—The University of Tennessee grating spectrometer has been used to examine some of the lines of the HF fundamental vibration spectrum, using samples containing HF at concentrations between 0.2 and 0.01 mole percent HF in various foreign gases. For the efficient foreign gas broadeners, at sufficiently high pressure, the lines are broad compared with the spectrometer transmission function, and the shape of the line can be directly observed with fair accuracy. This shape is determined by the foreign gas. The $R(0)$ and $R(1)$ lines of HF broadened with HCl at 5 atmos pressure are well described by a Lorentz line shape and are not shifted. The peak of the $R(0)$ line of HF broadened with SO_2 is shifted about +0.65 cm^{-1} at 5 atmos pressure, and the line shows a pronounced asymmetry about the peak, the high-frequency side being the stronger. With less-efficient broadeners the detailed shapes are obscured, but shifts are still observable. Shifts of the $R(0)$ line have been only toward high wave numbers when observable. Shifts of the other lines of the R branch have been only toward lower wave numbers when observable. The $R(4)$ line has been observed to shift with all broadeners studied, including oxygen.

B8. Comparison of Infrared and Cryoscopic Studies of Pyrrole Association in Nonpolar Solvents.* MARIE-LOUISE JOSIEN AND PAUL PINEAU, *Universite de Bordeaux,* AND NELSON FUSON, *Fisk University.*—Controversy[1] has arisen over the proposal[2,3] based on infrared spectroscopic measurements, that pyrrole-pyrrole association takes place through hydrogen bonding. It appeared of interest to us, therefore, to

restudy the behavior of pyrrole in solution by an entirely different method,[4] namely, the study of the effect of solution concentration on the fusion point temperature of pyrrole in cyclohexane. Comparison runs on phenol, well known to form hydrogen bonds, give results strikingly similar to those which we found for pyrrole. This paper summarizes the cryoscopic results together with their analysis which leads us to conclude we have further evidence for hydrogen bonding in pyrrole.

* Supported in part by National Cancer Institute and the Research Corporation.
[1] P. Tuomikoski, Mikrochim. Acta 505 (1955); J. phys. radium 16, 347 (1955).
[2] P. Mirone and M. Vampiri, Atti accad. Naz. Lincei, Mem. Classe Sci. Fis. mat. e nat. 12, 405 (1952).
[3] M. L. Josien and N. Fuson, J. Chem. Phys. 22, 1169, 1264 (1954).
[4] I. Prigogine and R. Defay, *Thermodynamique Chimique* (Editions Desoer, Paris, France, 1950), second edition, p. 434.

B9. Infrared Spectra of T_2O, THO, and TDO.* P. A. STAATS, H. W. MORGAN, AND J. H. GOLDSTEIN, *Oak Ridge National Laboratory.*—The vapor phase spectra of the tritiated water molecules have been observed in the 700- to 7000-cm^{-1} region with a Perkin-Elmer double-pass prism spectrometer. The fundamentals ν_2 and ν_3 were measured in T_2O and THO, and the fundamental ν_3 in TDO. Anharmonicity corrections have been applied to the experimental data, and the resultant zero-order frequencies compared to predicted values.[1] The discussion will include the techniques employed for synthesis and handling of the tritiated samples.

* This paper is based on work performed for the U. S. Atomic Energy Commission.
[1] W. F. Libby, J. Chem. Phys. 11, 101 (1943).

Invited Papers

B10. Some Infrared Researches on Line Widths and Line Shapes. SHIRLEIGH SILVERMAN, *Office of Naval Research.* (50 min.)

B11. Solid Phase Infrared Spectroscopy. JAMES R. LAWSON, *Tennessee A and I State University.* (30 min.)

Nuclear Instrumentation

(FRANCIS L. YOST presiding)

C1. Beta-Ray Spectroscopy at Very Low Energies. I. Detection Considerations. A. O. BURFORD, D. L. LAFFERTY, H. C. THOMAS, AND S. K. HAYNES, *Vanderbilt University.*—Successful utilization of a Geiger counter for detection of 100% of electrons below 5 kev will be discussed. A side-window counter whose efficiency is virtually independent of incident electron energy or counter pressure has been constructed and will be described. Windows for this counter are 11.2 cm^2 in area and are mounted on a circular 80-mesh per inch grid which is 31% transparent. The 4 $\mu g/cm^2$ collodion windows which are usable for 12 to 24 hours, can be made with 60% success; and 3 $\mu g/cm^2$ windows usable for 8 to 16 hours can be made with 40% success. Quality of a window is determined by the vacuum which can be maintained in a vacuum chamber with 1.5 cm Hg pressure in the counter. Best techniques for production of these films will be given. It has been found that a 6 $\mu g/cm^2$ window will transmit 100% of electrons to 4 kev or below and will cut off at 0.7 kev and that the 3 $\mu g/cm^2$ film will cut off at 0.5 kev.

C2. Beta-Ray Spectroscopy at Very Low Energies. II. *L*-Auger Spectrum of $Cs^{137}-Ba^{137}$. S. K. HAYNES AND A. O. BURFORD, *Vanderbilt University.*—The *L*-Auger spectrum of Ba^{137} from the disintegration of Cs^{137} which lies in the energy range 2.5–6 kev has been investigated with a thick lens beta-ray spectrometer with momentum resolution of 3%. This problem is of interest because it can give accurate values for *L*-fluorescence yields and because its application to isotopes which decay by orbital capture can yield information on the ratio of *L* to *K* capture. Source preparation for low-energy work involves not only the obvious problem of solids in the radioactive sample but also the question of proper grounding without excessive source backing; observed effects due to each of these difficulties will be discussed. The Geiger counter detector and the counter windows used for this study are described in the previous abstract. Values for the gross *L*-fluorescence yield of the Cs^{137} disintegration and somewhat less accurate values for the *L* II and *L* III subshell yields will be given. The reduced precision of the subshell yields arises from the failure of the spectrometer to resolve completely the various lines.

C3. Factors Involved in Satisfactory Operation of Wilson Chambers.* WILLIAM B. GOOD AND JAMES L. KASSNER, JR., *University of Alabama.*—This laboratory is concerned with the achievement of low background, together with maintenance of reasonable sensitive time in Wilson chambers.[1] We shall describe qualitative experiments on the following factors, among others: light filters; duration and magnitude of sweep field; effect of intermediate expansions; intentional addition of large amounts of volatile materials suspected as contaminants; structural improvements.

* Assisted by a grant from the National Science Foundation.
[1] H. C. Fitz and A. E. Ruark, Bull. Am. Phys. Soc. Ser. II, 1, 86 (1956).

C4. Linearity of a Cloud Chamber. C. C. SARTAIN, *Oak Ridge National Laboratory.*—The automatic cloud chamber developed by Saunders[1] has been used to count the number of aerosol particles per cm^3 for particles whose maximum linear dimension as determined by the diffusion method of Thomas[2] is as small as 10^{-2} micron. Since the particles are about two orders of magnitude smaller than the wavelength of visible light, one asks whether the number of water droplets photographed is proportional to the number of aerosol particles per cm^3. A tube bridge similar to that of Nolan and Pollak[3] was constructed to change the concentration of aerosol particles by accurately known ratios. These measured ratios agreed within statistical error (~1%) with the ratios of the number of droplets photographed in a small known volume.

[1] B. G. Saunders, ORNL-1957 (October 6, 1955).
[2] J. W. Thomas, ORNL-1648 (January 5, 1954).
[3] P. J. Nolan and L. W. Pollak, Proc. Roy. Irish Acad. **A51**, 9 (1946).

C5. Cloud Chamber for Counting Nuclei in Aerosols. BERNARD G. SAUNDERS, *Oak Ridge National Laboratory.*—A cloud chamber is described which measures either the absolute or relative concentration of nuclei in an aerosol. Water droplets are condensed on aerosol particles in a small sample, and the resulting water droplets are photographed on 16-mm film by flashtube illumination and then counted in a microprint reader. Two types of expansion cloud chambers were found to work satisfactorily: the volume defined and the pressure defined. The apparatus is completely automatic and will

operate continuously on a 1-min cycle. It can measure aerosol concentrations that range from 200 particles/cm³ to 2×10^6 particles/cm³.

C6. A Sensitive Current Integrator.* S. M. KINDALL AND R. C. MOBLEY, *Louisiana State University.*—An electronically timed current integrator has been developed which eliminates timing errors normally associated with current integrators using relays as their basic switching element. Integration is accomplished in the conventional fashion of charging a condenser to a negative voltage then discharging it with the proton beam caught in a Faraday cage and electronically turns off all associated measuring equipment when the voltage on the condenser has risen to zero. An unusual feature of this circuit is a clamp tube which delivers an electron current to the Faraday cage circuit keeping it at ground potential during the time the integration condenser is being relay switched from the charging to the integrating circuit. This eliminates any integration errors due to charge accumulation from the proton beam at the Faraday cage during switching. Integration begins when the electrometer circuit senses the connection of the negatively charged condenser to the Faraday cage and electronically switches on the associated measuring equipment. A unique auxiliary feature of this circuit is a combination of relays which can be preset to repeat the integration any desired number of times within the limits of the 38-step stepping relay.

* Work supported in part by the U. S. Atomic Energy Commission.

C7. A Recording Gamma Spectrometer.* W. H. VENABLE, JR., AND D. C. SWANSON, *University of Florida.*—A single-channel differential pulse-height analyzer was adapted to the automatic recording of differential pulse-height analysis curves for gamma-ray spectroscopy. This involved constructing a special count rate meter which would produce a smooth integration of the pulses fed to it so that the output could be read as the y deflection of an oscilloscope beam. In addition, there was the necessity of driving the base line dial of the analyzer and obtaining the base line setting in terms of the x deflection of an oscilloscope beam. The result is a versatile automatic-recording gamma-ray spectrometer which may be had by any laboratory possessing a single-channel differential pulse-height analyzer. The construction of the count rate meter will be discussed and typical curves will be shown.

* This work was supported in part by the U. S. Atomic Energy Commission and the Sperry Corporation (fellowship).

C8. Use of Scintillation Spectrometers in the Determination of Trace Elements in Sea Water. LAWRENCE K. AKERS AND ELIZABETH RONA, *Oak Ridge Institute of Nuclear Studies,* AND DONALD W. HOOD, *Texas A. & M.*—A project was started several months ago at ORINS with the collaboration of the Oceanographic Institute of Texas A & M to determine trace amounts of various elements in sea water. The samples were irradiated in the ORNL graphite reactor and, after some chemistry, were then counted. The scintillation spectrometer not only provides an aid in the identification of the various isotopes but also enables one to determine concentrations of one radioactive isotope in the presence of another. The spectrometers were equipped with either 3 in.×3 in. or 2 in.×2 in. NaI(Tl) crystals.

C9. A Magnet Design for a Spiral-Pole Electron Cyclotron. DONALD L. LAFFERTY, *University of Florida.*—The possibility of utilizing azimuthally varying magnetic fields to obtain the required vertical focusing for high-energy fixed-frequency cyclotrons has received considerable attention from the Berkeley and Oak Ridge Laboratories.[1,2] From the practical standpoint, one of the major problems in obtaining the necessary magnetic field is that of constructing pole faces which can be easily shimmed and readily varied to permit studies of the different spiral pole patterns. To provide the desired information on the characteristics of such a cyclotron, the design of the poles must be flexible enough to permit a wide variation in both the spiral and the number of poles. To achieve this extreme flexibility, the University of Florida model will have pole faces constructed of a large number of vertical steel elements arranged to give the spiraling hill-and-valley field. The elements will be set up in different spiral configurations and a very sensitive adjustment of the magnetic field will be possible by raising or lowering the individual elements. Slides of the proposed design will be shown and results of preliminary studies will be presented.

[1] David Judd, Phys. Rev. **100**, 1804(A) (1955); Pyle, Kelly, Richardson, and Thornton, Phys. Rev. **100**, 1804(A) (1955); Heusin Kveld, Jakobson, Ruby, Smith and Wright, Phys. Rev. **100**, 1804(A) (1955).
[2] D. S. Falk and T. A. Welton, Bull. Am. Phys. Soc. Ser II, **1**, 60 (1956); R. E. Worsham and R. S. Livingston, Bull. Am. Phys. Soc. Ser II, **1**, 60 (1956); H. M. Mosley and R. E. Worsham, Bull. Am. Phys. Soc. Ser. II, **1**, 60 (1956); T. A. Welton, Bull. Am. Phys. Soc. Ser II. **1**, 60 (1956).

C10. ORNL 625-kv Cascade Accelerator. C. D. MOAK AND R. F. KING, *Oak Ridge National Laboratory* (introduced by J. L. Fowler).—A low-voltage accelerator capable of delivering large beam currents has been put into operation at ORNL. The machine has been designed for two accelerator tubes, one of which will be used as a high-intensity neutron source. The other accelerator tube, now in operation, is equipped with a closed pumping system which is used when He^3 ions are accelerated. The He^3 tube stands on the floor below the high voltage generator; connection is made through the floor by means of a high-vacuum feed-through insulator. The accelerator has been provided with several new design features which provide reliability and ease of maintenance as well as a high degree of accessibility to all major parts. Performance figures for various feed gases will be reported. At present, the machine is being used to accelerate doubly charged He^3 ions for light element charged particle studies. Representative results will be described.

C11. Compound Electrostatic Lens for the ORNL 3-Mv Van de Graaff. C. H. JOHNSON AND J. P. JUDISH, *Oak Ridge National Laboratory* (introduced by J. L. Fowler).—Positive ions from the rf ion source probe canal are focused by an Einzel lens to an image 6 in. below the canal exit. This image is in a region of high-accelerating gradient which is produced by the main lens voltage across a ½-in. gap. The ions are accelerated in the gap and drift 7.5 in. to the accelerator tube entrance. The beam is brought to focus 100 in. beyond the exit of the 57-in. accelerator tube. Focusing conditions for the two lens elements are independent. The Einzel lens requires an accelerating voltage about 10 times the probe voltage, and the main lens must be about 1/60 times the accelerator tube voltage. The final image is less than 0.1-in. diameter or less than twice the probe canal diameter. Ion currents of 100 μa are readily obtained. These characteristics agree with predictions from electrostatic lens theory.

C12. Shielding of a Fast Power Breeder Reactor. H. E. HUNGERFORD, *Atomic Power Development Associates, Inc.*—The average energy at which fission takes place in a fast breeder reactor must be kept high in order that a significant breeding gain may be achieved. Light materials must not be present within either the core or the breeding blanket. This requirement complicates the shielding problems for a fast breeder since the energy spectrum of neutrons emerging from the blanket is quite different from that encountered in shields around thermal reactors. The method of removal cross sections which is extensively used in designing shields for thermal reactors tends to fail when applied to fast reactors on account of these differences. This paper will briefly discuss two methods which have been used in calculating the shield requirements

for the APDA fast breeder reactor. The first method employs the use of a slowing-down age-theory approximation which describes the neutron fluxes in terms of a slowing-down density q, an age τ, and a resonance escape probability p. The other method is the use of multigroup equations which are solved on a UNIVAC. Shield thickness may be established from the results of these calculations. A brief description of the APDA fast breeder reactor will be given.

(ARTHUR E. RUARK presiding)

Invited Paper

D1. Scientific and Technical Education in the U.S.S.R.: A Challenge to America (illustrated). HOMER L. DODGE, *president emeritus of Norwich University.* (1 hr.)

Discussion

Electrons and Ions

(RUSSELL BALDOCK presiding)

Invited Papers

E1. Mass Spectra of Polyatomic Molecules. HENRY ROSENSTOCK, *Oak Ridge National Laboratory.* (30 min.)

E2. Photodetachment Studies of Negative Ions. LEWIS M. BRANSCOMB, *National Bureau of Standards.* (30 min.)

Contributed Papers

E3. A New Mass Spectrometer. I. Theoretical.* GERTRUDE FLEMING REMPFER AND CONRAD HINDS, *Fisk University.*—When an ion of mass m, charge q, and initial velocity v, passes through a transverse magnetic field of length L (L being in the direction of the initial velocity), it acquires a lateral velocity

$$v_x = (HL/c)(q/m) \tag{1}$$

which does not depend on the initial speed. Ions of different q/m can be distinguished by measurement of the stopping potential

$$V_x = (1/2)(HL/c)^2(q/m) \tag{2}$$

corresponding to the lateral motion of the ions. A mass spectrometer operating on this principle would have the advantage that the resolution is not impaired by fluctuations in accelerating voltage or distribution in energy at the source. A simple instrument based on this theory is reported in Part II of this paper.

* Supported by a grant from the Research Corporation.

E4. A New Mass Spectrometer. II. Experimental.* HOWARD J. FOSTER AND G. F. REMPFER, *Fisk University.*—A small tube of simple design is being built to test the theory outlined in Part I of this paper. In this system the ions are accelerated from an ion source to an electrode at ground potential. An aperture in the grounded electrode allows ions to pass through a magnetic deflecting field and finally to a collecting chamber. The collector system consists of a grounded screen and a collecting plate. An adjustable retarding potential is applied between the screen and plate. The collector system is arranged in such a way as to measure the stopping potential corresponding to the lateral motion of the ions. We propose to test the theory by determining whether the lateral stopping potential is independent of the accelerating voltage of the ions.

* Supported by a grant from the Research Corporation.

E5. Electronic Analog of the Path of an Ion in Crossed Electric and Magnetic Fields of a Mass-Spectrometer Source.* JAMES W. MAYO AND HERMAN BRANSON, *Howard University.*—The magnetic field of a 60° mass-spectrometer source was measured and found to vary exponentially in the region of the source. Ion path equations were obtained from the Lorentz force equations as

$$m\ddot{x} = q\dot{y}B_0e^{-kx},$$
$$m\ddot{y} = qE - q\dot{x}B_0e^{-kx},$$

where B_0e^{-kx} is the variation of the magnetic field along the source axis. The ion trajectory in the source is traced by solution of these equations on an electronic analog computer.

* Supported in part by the Office of Naval Research.

E6. Effect of Geometry on the Current *vs* Pressure Characteristic of the Penning Discharge. W. E. DANCE AND D. C. RALPH, *Louisiana State University* (introduced by Max Goodrich).—An investigation has been made of the effect of electrode geometry on the Penning-type[1] discharge, or cold-cathode gas discharge in a magnetic field. Of primary interest in this study was the effect of anode diameter and distance between cathode plates on the current-pressure characteristic of the discharge. A series of eleven electrode arrangements was constructed, the anode diameter ranging from 2 mm to 50 mm, and the distance between cathode plates ranging from 5 mm to 50 mm. Cylindrical anodes, which permit greater discharge currents and better stability than do ring anodes, were used.[2,3] Discharge currents for air were observed as a function of pressure, voltage, and magnetic field. It is found that below 0.2 μ of Hg the current-pressure characteristics are linear for logarithmic plots, the slopes being comparatively independent of geometry. The discharge current i in ma is proportional to $(pl)^c$, where p is the pressure in microns of Hg, l the distance in

cm between cathode plates, and c a constant approximately equal to unity.

[1] F. M. Penning, Physics **3**, 873 (1936).
[2] F. M. Penning and K. Nienhuis, Phil. Tech. Rev. **11**, 116 (1949).
[3] Hayashi *et al.*, Rev. Sci. Instr. **20**, 524 (1949).

E7. Charge States of Rb^{85} following Beta Decay of 9.4-Year Kr^{85}. ARTHUR H. SNELL AND FRANCES PLEASONTON, *Oak Ridge National Laboratory.*—Magnetic analysis has been used to measure the charge spectrum of the rubidium atoms produced in the radioactive decay of Kr^{85}. This 9.4-year activity is almost a pure beta emitter. The results which are still provisional in that pressure effects in the apparatus have not yet been investigated, are as follows:

Charge	Percent of decays	Charge	Percent of decays
1	75.60	7	0.51
2	12.57	8	0.25
3	4.50	9	0.11
4	3.56	10	0.04
5	2.09	11	Sought, not found
6	0.77		

The charge 1 ions represent the clean emission of the negative beta particle; charge 2 and higher represent the cases in which beta emission is accompanied by some kind of an atomic ionization event. The totality of ions of charge 2 and higher indicates that ionization takes place in 25% of the decays. This is considerably more than would be suggested by present theory. The shape of the charge spectrum indicates that most of the electrons are removed from the outer shells; this is qualitatively in agreement with theory when screening is taken into account, for the probability of ionization is expected to go as $1/Z^2_{eff}$.

E8. Electron Drift Rate in Pure Gases and Gas Mixtures. T. E. BORTNER AND G. S. HURST, *Oak Ridge National Laboratory.*—An apparatus has been designed and constructed to measure the electron drift rate in gases as a function of the electrical field. The source of electrons is the ionization of the gas by a collimated alpha source (Pu^{239}). The rate of drift in nitrogen is not measurably affected by as much as 3% of oxygen, while in methane there is a definite change. Electron drift rates will be shown graphically in methane, argon, nitrogen, carbon dioxide, and in mixtures of some of the gases. In very fast gases such as methane the time interval of electron transport is very short and small changes in time were difficult to determine. A null method of reading the time differential was developed.

E9. Electron Attachment Values for Propane Flame Particles. M. J. SAUNDERS AND A. G. SMITH, *University of Florida.*—The method of phase contrast telescopy[1] has been applied to a study of propane gas flames. Application of a dc electric field, transverse to the direction of flow of the gases, causes the central column of gas to separate, one branch of the column possessing a positive, and the other a negative charge. By fitting a parabola to the negative branch, one obtains a value for $N/m = 1.03 \times 10^{16}$ electrons/particle/gram, where m = mass of a particle in grams and N = number of electrons/particle. When a microscope slide, covered with a thin film of immersion oil, is attached to the positive electrode and the voltage adjusted until the negative beam strikes the slide, some of the particles are captured and their sizes may be determined. On the assumption that the particles are carbon, the masses of the particles can be calculated. The value of N varies from 2 to 20 electrons/particle.

[1] M. J. Saunders and A. G. Smith, J. Appl. Phys. **27**, 115 (1956).

E10. A Study of Multiple Scattering of 280- to 450-kev Electrons in Gold Foil. J. B. DICKS* AND J. I. HOPKINS, *Vanderbilt University.*—A β emitter was placed in a Wilson cloud chamber having an applied magnetic field and located in a holder so constructed that only electrons of a chosen range of velocities would reach the chamber. After leaving the velocity selector the electrons struck a gold foil, of average area density 0.00278 g/cm², normally. A total of 10 600 pictures was taken. Of these, 890 were analyzed by the method of Dicks and Hopkins.[1] The tracks were classified into three energy ranges. Slides showing the relative height of the experimental and theoretical scattering probability curves will be shown. The theoretical curves were calculated from the work of Goudsmit and Saunderson.[2]

* Now at the University of the South, Sewanee, Tennessee.
[1] J. B. Dicks and J. I. Hopkins, Rev. Sci. Instr. **26**, 1061 (1955).
[2] S. A. Goudsmit and J. L. Saunderson, Phys. Rev. **57**, 24 (1940).

Nuclear Physics

(J. L. FOWLER presiding)

F1. Fast Decay Measurements with Pulsed Neutron Source. E. C. CAMPBELL AND P. H. STELSON, *Oak Ridge National Laboratory.*—Measurements of delayed nuclear effects resulting from fast neutron bombardment of a target have been made with the ORNL 5.5-Mev accelerator used as a square-wave modulated neutron source of variable frequency and with a synchronized multichannel time analyzer. By variation of the frequency of the master control oscillator half-life measurements in the whole range from seconds to microseconds can be made. Two classes of experiments are reported: (1) production of metastable nuclear states by fast neutrons, as, for example, in the reaction $Ta^{181}(n,n')Ta^{181m}$ (22 μsec); (2) measurement of rates for leakage and absorption of thermalized neutrons in H_2O and in Be. Evidence for the existence of higher modes as predicted by diffusion theory has been obtained from the analysis of the measured space and time dependence of a neutron burst leaking from a Be block.

F2. (n,p) Cross-Section Measurements at Medium Energies. H. G. BLOSSER AND T. H. HANDLEY, *Oak Ridge National Laboratory.*—A number of (n,p) reaction cross sections have been measured in the region of the periodic table from $28 \leqslant Z \leqslant 33$. Cross sections were measured by activation, utilizing a comparison technique in which the activity to be measured is compared with that resulting from a known cross section. Difficulties with absolute flux determination are hence eliminated. Chemical separations were used to separate the (n,p) product element from the target material in those cases where strong $(n,2n)$ activities interfered with identification of the (n,p) product. Results have been obtained at neutron energies of from 12 to 16 Mev. Most of the cross sections thus far observed are decreasing with increasing energy. It is thus implied that (n,pn) cross sections are quite substantial at these energies. Estimates of the size of these (n,pn) cross sections indicate the probability of proton emission in these reactions to be quite consistent with that observed in 22-Mev proton induced reactions. The anomalous difference in the proton emission from proton *vs* neutron induced reactions, pointed out by Cohen and Newman,[1] is hence apparently resolved.

[1] B. L. Cohen and E. Newman, Phys. Rev. **99**, 718 (1955).

F3. Neutron Thresholds from Alpha-Particle Bombardment of F^{19}, Na^{23}, and Al^{27}.* B. S. BURTON AND R. M. WILLIAMSON, *Duke University* (introduced by H. W. Lewis).—The energies of alpha particles from a Van de Graaff accelerator were determined by a cylindrical electrostatic analyzer[1] relative to the Li(p,n) threshold[2] of 1.8811 Mev. Data taken with H^+ and HH^+ bombarding particles on (p,γ) resonances near 1- and 2-Mev incident energy showed that the analyzer was accurate to 0.1% in energy for energy comparisons between 1 and 4 Mev. The aim of the measurements was to find reactions suitable for alpha-particle energy calibration as well as to help fix the masses of the product nuclei. Preliminary data give thresholds of 2.486 and 3.409 Mev for F and Al, respectively. A further search for possible weaker thresholds at lower alpha energies is in progress. Another uncertainty is the L_n of the outcoming neutrons and the shape of the neutron-yield curve. Thin target F data may be fit assuming either $L_n=1$ or 2. The true threshold in the latter case is 3 kev lower than in the former. A further study of stronger (α,n) and (α,γ) resonances is in progress.

* This work was supported by the U. S. Atomic Energy Commission.
[1] Warren, Powell, and Herb, Rev. Sci. Instr. **18**, 559 (1947).
[2] Jones, Douglas, McEllistrem, and Richards, Phys. Rev. **94**, 947 (1954).

F4. $Si^{28}(p,p'\gamma)Si^{28}$ Reaction. H. B. WILLARD, J. K. BAIR, H. O. COHN, AND J. D. KINGTON, *Oak Ridge National Laboratory* (introduced by S. K. Haynes).—Angular distributions (with respect to the incoming proton) of the 1.78-Mev gamma ray produced by inelastic scattering of protons by Si^{28} have been measured at and in between each of the 8 resonances previously reported.[1] The detector was a NaI, 3 in.×3 in., crystal located 50 cm from a 2-kev thick $Si^{28}O_2$ target. For this particular case the spin but not the parity of the levels formed in the compound nucleus P^{29} can be inferred. An absolute zero-degree differential cross section at the peak of the 3.10-Mev resonance has been obtained by two independent methods yielding the value 64±12 millibarns/steradian. A run with points spaced less than 1 kev apart revealed 5 additional very narrow low-intensity resonances at 2.64, 3.88, 3.93, 3.97, and 4.93 Mev.

[1] Cohn, Bair, Kington, and Willard, Phys. Rev. **99**, 644(A) (1955).

F5. Neutron Activation of Iodine near 25 kev. R. L. MACKLIN, *Oak Ridge National Laboratory*.—The cross section for $I^{127}(n,\gamma)I^{128}$ (25-min β emitter) has been measured with a standardized antimony-beryllium neutron source. NaI(Tl) crystals were activated at measured distances from the source, and the beta particles detected by scintillation counting.[1] Corrections were measured or computed for neutron energy spectrum, source asymmetry, effective center displacement, scattering in NaI(Tl), and beta-detection efficiency. The activation cross section found was 0.82±0.06 b for neutron energies near 25 kev. The early work of Linenberger and Miskel at Los Alamos at several energies gives an interpolated value of about 1 b with perhaps 0.2- to 0.3-b uncertainty. The 2.2-b (±0.4 b) value obtained by Hummel and Hamermesh[2] with an antimony-beryllium source is in disagreement with the present result.

[1] H. C. Martin and R. F. Taschek, Phys. Rev. **89**, 1302 (1953).
[2] V. Hummel and B. Hamermesh, Phys. Rev. **82**, 67 (1951).

F6. Polarization of γ Rays in Ta^{181}. P. H. STELSON AND F. K. MCGOWAN, *Oak Ridge National Laboratory* (introduced by J. L. Fowler).—The decay of Hf^{181} excites states in Ta^{181} at 137, 480, and 612 kev. Directional correlation measurements of the γ rays indicated two possible spin assignments for the 480- and 612-kev states.[1,2] Calculation of the expected polarization of the 480-kev γ rays in the 137- to 480-kev decay showed that this property was quite different for the two spin assignments. For the spin assignment 480, $9/2^+$ and 612, $5/2^+$ the calculated value of p is 1.10 where $p\equiv W(90°,90°)/W(90°,0°)$ in the notation of Biedenharn and Rose.[3] For the spin assignment 480, $5/2^+$ and 612, $1/2^+$ the value for p is 0.67. The experimental value for liquid HfF_4 source is 0.71±0.05. To check on possible systematic errors, measurements were also made with a dry HfF_4 source for which one expects an attenuated value for p of 0.91. The experimental value is 0.88±0.05. We conclude that the correct spin assignments are 480, $5/2^+$ and 612, $1/2^+$.

[1] F. K. McGowan, Phys. Rev. **93**, 163 (1954).
[2] H. Paul and R. M. Steffen, Phys. Rev. **98**, 231 (1955).
[3] L. C. Biedenharn and M. E. Rose, Revs. Modern Phys. **25**, 729 (1953).

F7. Directional Correlation of Gamma Rays in the Decay of Ir^{192}.* V. W. SHIEL, L. D. WYLY, AND C. H. BRADEN, *Georgia Institute of Technology*.—The directional correlations of three gamma-ray cascades in Pt^{192} following the beta decay of Ir^{192} have been measured. The (468) (316) kev gamma cascade gives $A_2=0.088\pm0.006$ and $A_4=0\pm0.01$. These values agree with those previously reported.[1] The (604) (316) kev gamma cascade gives $A_2=-0.21\pm0.01$ and $A_4=0\pm0.02$. The (612) (589) kev gamma cascade gives an anisotropy ratio of 0±0.04. Assuming pure $E2$ radiations and a spin of 2 for the first excited state of Pt^{192}, the (604) (316) kev directional correlation indicates a spin of 3 should be assigned to the excited state at 921 kev.

* This work supported in part by a grant from the National Science Foundation.
[1] Baggerly, Marmier, Boehm, and DuMond, Phys. Rev. **100**, 1364 (1955).

F8. Internal Bremsstrahlung from Y^{90}. M. A. HAKEEM AND MAX GOODRICH, *Louisiana State University*.—The internal bremsstrahlung spectrum of the first-forbidden beta-emitter Y^{90} has been studied with a scintillation spectrometer employing a cylindrical NaI crystal, 3 in.×3 in. The geometrical arrangement was similar to the one used in previous internal bremsstrahlung measurements[1] made in this laboratory. The shape of the experimental spectrum, measured out to 1700 kev, has been compared to that of the theoretical spectrum as given in the paper of Bolgiano *et al.*[2] after correcting the theory curves for the crystal response. The results show that, in the middle region of energies, the experimental spectrum rises significantly above the theoretical spectrum. This is in contrast to the results from the earlier measurements with P^{32}, which have been confirmed with the present equipment and which show good agreement between theory and experiment out to 950 kev. The contribution of random sum pulses to the shape of the spectrum was investigated and found to be negligible.

[1] Goodrich and Payne, Phys. Rev. **94**, 405 (1954).
[2] Bolgiano, Madansky, and Rasetti, Phys. Rev. **89**, 679 (1953).

Invited Papers

F9. Studies of Intermediate and Heavy Nuclei with Neutrons. H. H. BARSCHALL, *University of Wisconsin*. (30 min.)

F10. Yields, Angular Distributions, and Polarization of Gamma Rays from Coulomb Excitation. F. K. MCGOWAN, *Oak Ridge National Laboratory*. (30 min.)

General Physics

(D. R. McMillan presiding)

G1. Apparatus for the Measurement of the Absorption and Velocity of Sound in Gases. Robert Lagemann and Doug Shields,* *Vanderbilt University.*—An apparatus has been designed to investigate both tube and relaxation absorption in the f/p range from 8 to 2000 kc/atmos. It is patterned after that of Angona[1] with certain changes which make possible measurements at temperatures between 0 and 200°C. The measurements are made on gases enclosed in a precision bore Pyrex glass tube 130 cm long and 1.73 cm inside diameter. This tube is vacuum tight and encloses a movable sound speaker in one end and a stationary receiver in the other. The complete tube is enclosed in a temperature control box with the position of the speaker controlled and measured from outside this box. The absorption is obtained from measurements of the sound intensity at the receiver as the path distance between the speaker and receiver is varied. The wavelength is the distance between points where the receiver and speaker signals are in phase. The sound frequency is maintained low enough to insure only plane waves. The sound tube and receiver are designed to eliminate standing waves.

* Now at Middle Tennessee State College.
[1] F. A. Angona, J. Acoust. Soc. Am. **25**, 1111 (1953).

G2. Absorption of Sound in Argon, Nitrogen, and Carbon Dioxide between 0° and 200°C. Doug Shields, *Middle Tennessee State College.*—The absorption of sound in gases is attributed mainly to three effects; viscose and heat conduction losses, losses to the walls of the tube (when the sound is confined to a tube), and thermal relaxation losses. The first two of these effects have been investigated in the temperature interval between 0 and 200°C in argon and nitrogen using the apparatus previously described. The frequency was varied from 2 to 11 kc and the pressure from 4 mm to 20 cm. The results are adequately explained by the Kirchoff theory. Measurements were made in carbon dioxide at 7 temperatures between 0 and 200°C. In this case the absorption due to thermal relaxation was isolated by subtracting the classical and tube absorption (as calculated by the Kirchoff theory) from the measured absorption. When this relaxation absorption was plotted against the log of f/p the resulting bell-shape curves indicated all the vibrational modes relax with a single relaxation time. The temperature variation of the collision efficiency (as calculated from the relaxation times) is that predicted by the Landau-Teller equation.

G3. Dielectric Relaxation of Mixtures of Dipolar Liquids at Microwave Frequencies. P. K. Kadaba, *University of Kentucky* (introduced by Nelson Fuson).—In his investigation at 9 Mc/sec on binary dipolar mixtures of liquids of a somewhat complex nature, Schallamach[1] has explained the absence of two dispersion ranges by assuming that the relaxation process involves the disturbance of a relatively large region in the liquid. In order to estimate the size of these regions, microwave absorption measurements, on ternary mixtures of nitriles, aliphatic nitrocompounds or nitrobenzene and nitrates of appropriate molecular weight in a neutral solvent such as a paraffin, are suggested. At low concentrations where the separation of the dipolar molecules of the two species is large, we would expect two peaks of the loss curve, but at higher concentrations when the molecules can interfere with each other one maximum only should be found. Thus it would be possible to estimate the size of the volume involved in dielectric relaxation. In the preliminary results obtained by me for the mixture of nitrobenzene and nitroethane in heptane at a frequency of 14 285 Mc/sec for a relatively high concentration of the dipolar components (mole fraction of 0.04 for nitrobenzene and 0.06 for nitroethane) there are clearly still two distinct relaxation ranges present. These results will be discussed.

[1] A. Schallamach, Trans. Faraday Soc. **A42**, 180 (1946).

G4. A Dicke-Type Microwave Radiometer for 7- to 8-mm Wavelength.* F. H. Mitchell, R. N. Whitehurst, and Jack Copeland, *University of Alabama.*—A Dicke-type microwave radiometer has been constructed for the 7- to 8-mm wavelength range. This instrument continuously compares the radiation received by an 18-in. paraboloidal antenna to the thermal noise power available from a resistance matched to the wave-guide feed. The difference in power is proportional to the difference between the effective temperature seen by the antenna beam and the temperature of the comparison resistance. The design features of the radiometer will be described and some results presented.

* This work has been supported by the University of Alabama Research Committee.

G5. Solar Radiation and Atmospheric Attenuation Measurements in the 7- to 8-mm Wavelength Range.* R. N. Whitehurst, F. H. Mitchell, and Jack Copeland, *University of Alabama.*—Measurements of solar radiation and atmospheric attenuation have been made with the microwave radiometer described in another paper.[1] The apparent temperature of the sun has been determined to be 6000 ± 500°K at a wavelength of 7.5 mm. The total vertical attenuation of the atmosphere has been measured as 0.3 to 0.6 db for various atmospheric conditions. The measurement procedure will be described and more detailed results presented.

* This work has been supported by the University of Alabama Research Committee.
[1] Mitchell, Whitehurst, and Copeland, preceding abstract.

G6. A Study of the Rossi Transition Curve for Cosmic-Ray Showers. Paul F. Haughton* and Eric Rodgers, *University of Alabama.*—A search has been made for a second maximum in the Rossi transition curve. Under the conditions of the experiments, a second peak was found at approximately 210 grams per square centimeter of iron as absorber. The experiments will be described.

* Now at Oak Ridge National Laboratory.

G7. Effect of Atmospheric Turbulence on Photographic Resolution. A. G. Smith, M. J. Saunders, and M. L. Vatsia,* *University of Florida.*—A systematic, statistical study is being made of the effect of atmospheric turbulence on photographic resolution. Among the factors which are being evaluated are the effects of exposure time and distance of the disturbance from the camera. Experiments are being conducted on an indoor range under controlled conditions, as well as out-of-doors. Phase contrast photographs[1] of the optical path are being made in some cases for correlation with the measured resolutions.

* Sponsored by the Office of Ordnance Research, U. S. Army.
[1] M. J. Saunders and A. G. Smith, J. Appl. Phys. **27**, 115 (1956).

G8. On the Boundary between Fresh Water and Salt Water in an Estuary. John R. Hatcher, *Fisk University* (introduced by Nelson Fuson).—This paper is concerned with determining the shape and position of the so-called "salt wedge," i.e., the underlying layer of sea water which intrudes upstream in the region near the mouth of some rivers and canals (e.g., in the Mississippi River). The author's work parallels that of Sanders, Maximon, and Morgan. The essential difference is in the assumption concerning certain stress quantities. By means of an

averaging process differential equations are formed for the curves corresponding to the free surface and the interfacial boundary. The main results are the approximations

$$H^2[1-a/(1-H)^{-2}]=2\gamma a\lambda\delta, \quad H^{*-3}=2a\gamma\lambda, \qquad (1)$$

where H is the approximate dimensionless thickness of the salt wedge, δ the dimensionless horizontal coordinate, a the interfacial Froude number, γ a dimensionless constant, λ a dimensionless length parameter, and H^* the maximum value of H (at the end of the wedge). Curves corresponding to (1) agree very well with available experimental data. The present theory holds promise of yielding results which may be sufficiently accurate for engineering purposes.

G9. On the Kinetic Energy of the Visible Universe. ARTHUR E. RUARK, *University of Alabama*.—The view has been widely entertained that the elements arose from the explosion of a neutron ball, substantially cold. Alpher, Follin, and Herman[1] considered a ball with particle energies up to 100 Mev. Suppose we assume Euclidean space time, Hubble's linear law, and uniform distribution of the visible matter. We calculate the average kinetic energy T per *nucleon*, relative to ourselves, for the available sample of space, treating the red shift as a Doppler shift. The result is $(Mc^2)(3/10)(V/c)^2$, where V is the greatest speed observed, and M the nucleon mass. From results of Humason, Mayall, and Sandage, we use $V=0.2c$. Then T is 11 Mev; this is *independent* of the value of Hubble's constant. It is far more than can be obtained from neutron decay (0.3 Mev) without doing violence to the above assumptions. Consideration of the released binding energy of helium, etc., does not help much. I am aware that in some interpretations of universal expansion the matter may be "just carried by the expanding space," so that kinetic energy requires no explanation. The reader may draw his own conclusions.

[1] Alpher, Follin, and Herman, Phys. Rev. **92**, 1347 (1953).

G10. Modal Deviation from Most-Probable Configurations. ROBERT W. REMPFER, *Fisk University* (introduced by G. F. Rempfer).—In case of the simplest distributions of statistical mechanics, the most-frequent deviation from the configuration of maximum probability density has a value which depends on the number of dimensions of the configuration, as well as on the number of particles. It may be of pedagogical interest that this resembles other situations where statistics is used, such as applications of the chi-square test. Occasionally such situations, from social science, say, can be given a statistical-mechanical analog.

G11. Analog Computer Solutions of a Set of Diffusion Equations.* HERMAN BRANSON, *Howard University*.—In the study of the movement of PO_4 using P^{32} into an enclosure where the volume and surface are changing, we have encountered the following system of equations[1]:

$$\frac{ds}{dt}=K_1A\left(C_s-\frac{s}{v}\right),$$

$$\frac{dv}{dt}=K_2A\left(\frac{a-s}{v}-C_m-C_s\right),$$

$$\frac{dA}{dt}=4\left(\frac{\pi}{A}\right)^{\frac{1}{2}}\frac{dv}{dt}.$$

The first two equations are general; the third applies to a spherical enclosure. The analog computer solutions (HUEAC) for this system with A = constant will be discussed.

* Supported in part by the U. S. Atomic Energy Commission and the Office of Naval Research.

[1] Davson and Danielli, *Permeability of Natural Membranes* (Cambridge, 1943), p. 45.

G12. Elementary Explanation of Temperature Inversion in Thermal Diffusion. R. D. PRESENT, *The University of Tennessee*.—The thermal-diffusion constant a is known to decrease with decreasing temperature and may even change sign, e.g., in isotopic NH_3 mixture[1] where the sign change occurs at 20°C. Detailed calculations by the Enskog-Chapman method using the Lennard-Jones (6–12) potential give fair agreement with experiment.[2] An elementary explanation of thermal diffusion has been advanced by Frankel[3] and elaborated by Furry.[4] These authors consider only the case of an inverse power repulsion between point molecules and in this case a is independent of temperature. It is shown here that Frankel's arguments, used in conjunction with an approximate version of the Sutherland molecular model, provide a very simple explanation of the temperature dependence of a in qualitative agreement with experiment.

[1] W. Watson and D. Woernley, Phys. Rev. **63**, 181 (1943).
[2] Hirschfelder, Curtiss, and Bird, *Molecular Theory of Gases and Liquids* (John Wiley and Sons, Inc., New York, 1954).
[3] S. Frankel, Phys. Rev. **57**, 660 (1940).
[4] W. H. Furry, Am. J. Phys. **16**, 63 (1948).

Biophysics

(JOHN KIRBY-SMITH presiding)

Invited Paper

H1. Physical Measurements on Animal Virus. GORDON SHARP, *Duke University Medical School*. (1 hr.)

Contributed Papers

H2. Electron-Spin Resonance in X-Irradiated Single Crystals of Amino Acids.* AREND VAN ROGGEN, LIEN VAN ROGGEN, AND WALTER GORDY, *Duke University*.—A single crystal of *D*-alanine has been x-irradiated and its electron spin resonance observed at different orientations in the magnetic field. For H parallel to the crystalline axis a quintet with sharp components and a total spread of 100 gauss is observed. For orientations perpendicular to the axis the same quintet is still evident but now has a finer structure, a doublet or triplet, depending on the orientation, superimposed upon each of its components. The quintet is believed to arise from the $(C_2H_4)^+$ radical as postulated[1] for the similar resonance of the powder. Its spacing appears to be independent of crystal orientation if the finer splitting of each component is integrated. This would suggest that the quintet coupling results mainly from the nonvanishing density $\Psi_0\Psi_0^*$ at each of the 4 hydrogen nuclei as earlier proposed.[1] However, the orientation dependence of the finer splitting indicates that motions of the radical are highly restricted. The finer structure may arise from nearby but nonbonded protons coupled through dipole-dipole interaction to

the electron spin or possibly from an anisotropy in the g factor of the radical. Single crystals of other amino acids are being prepared for investigation.

* Supported by the Office of Ordnance Research, U. S. Army.
[1] Gordy, Ard, and Shields, Proc. Natl. Acad. Sci. **41**, 996 (1955).

H3. Electron-Spin Resonance of X-Irradiated Nucleic Acids.* HOWARD SHIELDS AND WALTER GORDY, *Duke University.*—We have observed the electron spin resonances of the nucleic acids and certain of their constituents after x-irradiation. The resonances of DNA and RNA are similar and consist of a strong component of g factor 2.00 and a weak satellite. Some of their constituents gave more complex resonances. The resonance of thymidine, for example, has a proton hyperfine structure of 7 components. That of guanosine is a triplet with broad components suggesting further unresolved structure. Guanylic acid exhibits a triplet immediately after irradiation, but upon exposure to air the triplet is slowly converted to a singlet. Adenosine, also muscle adenylic acid, gave a strong central component with weak side lobes. Cytidine, cytidylic acid, adenosine, and inosine gave only single resonances with g factors of 2.00. These resonances are being investigated further under different physical conditions in the hope of finding out something of the mechanism of radiation damage to the cell nucleus.

* Supported by the Office of Scientific Research, U. S. Air Force.

H4. Effects of Temperature and Isomeric Structure on the Electron-Spin Resonance of X-Irradiated Amino Acids.* WALTER GORDY AND HOWARD SHIELDS, *Duke University.*—At the temperature of liquid nitrogen the paramagnetic resonance patterns of x-irradiated glycine, valine, and leucine become more complex and less resolvable than those which have been observed at room temperature.[1] These changes may indicate the quenching of certain types of motions which at room temperature tend to reduce anisotropic interactions, or they may indicate structural changes in the radicals themselves or in their immediate surroundings. The only noticeable effect of cooling to 77°K on the alanine quintet is almost to equalize the intensities of the five components. The reason for this strange effect is not evident. Samples of irradiated alanine and glycine were heated to temperatures near their melting point without destruction of their resonances. Preliminary evidence indicates that it is much more difficult to produce resonances in alanine when it is irradiated at liquid air temperature than when irradiated at room temperature. Other amino acids and proteins are being investigated for this effect which suggests that temperature may have an important effect on radiation damage. Noticeable difference in the effects of ionizing radiations has been detected for different isomeric forms of leucine: *DL*-leucine gives a sextet hyperfine structure; *DL*-isoleucine, a symmetrical seven-component structure; $L(-)-$ leucine, a triplet with shoulders like the pattern for irradiated glycine. In contrast, the patterns obtained for *D*- and *L*-alanine are alike. Other isomeric forms are under investigation.

* Supported by the Office of Scientific Research, U. S. Air Force.
[1] Gordy, Ard, and Shields, Proc. Natl. Acad. Sci. **41**, 996 (1955).

H5. Ionization in a Cavity in a Beta-Radioactive Medium. R. D. BIRKHOFF, H. H. HUBBELL, JR., AND R. M. JOHNSON, *Oak Ridge National Laboratory.*—A part of a program for measuring the spectral distribution of electron flux and resulting ionization in irradiated media has been the determination of ionization in cylindrical ion chambers placed in a cavity in a beta-radioactive solution. Using the Bragg-Gray principle, a calculation of the ionization in an unshielded cavity is made from knowledge of the beta spectrum and specific activity of the radioisotope. With a 1 mg/cm² mylar foil separating the cavity from the solution, ionization varied from 75% of the calculated value for S^{35} (mean energy of 55 kev) to 100% for P^{32} 493 kev. A chamber with a 7 mg/cm² conducting paper wall (equivalent to human epidermis) inserted into the cavity had a response from 10 to 95% of the calculated values for mean energies in the cavity from 55 kev to 654 kev. When this was reinforced with a perforated aluminum, magnesium, or plastic sheet, a practical personnel beta dosimeter with response 50% or more of the paper chamber was obtained. Other calibration sources were Ca^{45}, W^{185}, Sn^{121}, Tl^{204}, Bi^{210}, Ag^{111}, and Y^{90}. X-ray response was found to be nearly identical to the standard pocket chamber under field conditions where secondary electrons are usually in equilibrium.

H6. Radiation-Induced Changes in Muscle Fiber Membrane Potentials. EDGAR B. DARDEN, JR., *Oak Ridge National Laboratory.*—A reduction in resting membrane potentials was observed in fibers of excised frog sartorius muscles following exposure to doses of $\sim 10^5$ r ionizing radiation. The potential difference was measured between a 118-mm KCl-filled ultramicroelectrode (diam of tip $<1\mu$, dc impedance $\sim 2\times 10^8$ ohms) inserted through the wall of the fiber and an electrode in the insulated muscle bath (Ringer's solution).[1] The signal was applied via agar Ag−AgCl electrodes to a commercial vibrating reed electrometer and an ink recorder. The muscle was exposed to 250-kvp X or cobalt-60 γ rays, the unirradiated muscle from the other leg serving as control. Following irradiation or treatment with other deleterious agents, the potentials of randomly selected fibers declined, with large individual variations in time of onset and rate of fall. Association of subnormal potentials with latent fiber damage was emphasized by the subsequent appearance of histological changes at sites of minimum potential.

[1] Ling and Gerard, J. Cellular Comp. Physiol. **34**, 383 (1949).

H7. Application of Fast Neutrons to Radiobiology. M. L. RANDOLPH, *Oak Ridge National Laboratory.*—A commercial Cockcroft-Walton 250-kv accelerator[1] with a focused 800 μa beam[2] produces monoenergetic fast neutrons of two energies by the $T(d,n)He_4$ or $D(d,n)He_3$ reaction. Biological responses of small sensitive materials, accurately placed near the target, are determined after irradiation. Dosimetry and yield constitute the physical problems. A thin layer of flowing water cools zirconium hydride targets. Maximum d-t and d-d dose rates used are 20 and 0.6 rep/min at 5 cm. Simultaneous independent measurements yield the dose accurately. The neutron flux is determined from the associated charged particle flux and from a calibrated long counter.[3] The dose in tissue is calculated from the chemical composition and nuclear cross sections. The total ionization in hydrogenous homogeneous chambers is determined by current measurements[4] or integrating the pulse-height distribution curve from a proportional counter.[5] The dose is calculated from W for the chamber gas or α-particle calibration, and the dose ratio for tissue to gas.

[1] Bergstralh, Dunning, Durand, Ellison, Howerton, and Slavin, Rev. Sci. Instr. **24**, 417 (1953).
[2] Moak, Reese, and Good, Nucleonics **9**, No. 3, 18 (1951).
[3] Hanson and McKibben, Phys. Rev. **72**, 673 (1947).
[4] Darden and Sheppard, ORNL-1002 (1951).
[5] G. S. Hurst, Brit. J. Radiol. **27**, 353 (1954).

H8. New Fractionation Methods for Isolating Cellular Proteins. NORMAN G. ANDERSON, *Oak Ridge National Laboratory* (introduced by John Kirby-Smith).—Two new devices that facilitate the fractionation of suspensions of cell organelles and the recovery of specific proteins from the fractionated material are described. The first device is an open-bowl centrifuge head designed so that a liquid density gradient may be introduced into it while in rotation. A suspension of tissue organelles is introduced onto the inner edge of the gradient. Fractionation of the particles occurs as they are centrifuged out through the gradient. A very dense fluid is introduced at the outer edge of the liquid gradient, moving the gradient to the center of the centrifuge head, where it is drained out and the desired fractions recovered. The second device is an electrophoretic sepa-

rator that overcomes several of the difficulties previously encountered in fractionating protein mixtures in free liquid or on conventional horizontal starch blocks. The protein mixture is supported in a thin layer of starch which is applied to a thicker layer of starch containing the buffer used. This double layer is supported perpendicularly between cellophane (on the protein side) and filter paper (on the protein-free starch side). A second sheet of cellophane is supported parallel to the filter paper a short distance in front of it. Parallel platinum electrodes provide a uniform electrical field. The whole device is supported in cold, rapidly circulating buffer. The proteins move only a short distance through the starch sheet, pass through the filter paper, and are collected in the space between the filter paper and cellophane where some concentration caused by electroconvection occurs. The application of these techniques to the purification of mammalian liver fractions is described.

H9. Spectrographic Analysis of Human Tissue. ISABEL H. TIPTON, *The University of Tennessee and Oak Ridge National Laboratory*, AND ROBERT L. STEINER AND WILLIAM D. FOLAND, *The University of Tennessee.*—The program for spectrographic analysis of human tissue which was set up at The University of Tennessee in 1951 has completed the preliminary phase of its work. Quantitative methods for the analysis of tissue ash for 30 elements by the use of internal standards have been worked out. Since the program for collecting and ashing samples has been set up in the Health Physics Division of the Oak Ridge National Laboratory, it is now possible for the spectrographic laboratory to proceed at the rate of some 1200 determinations per week. The high cadmium content of the kidney which was reported before the Southeastern Section of the American Physical Society in 1952 continues to appear, the average value for the kidneys of 49 adult victims of instantaneous death in 3 cities being 30 micrograms per gram of wet tissue. The work is continuing. Analyses of at least twenty-five autopsies from each of fifteen cities will make possible a statistical study of the geographical variation in trace element concentration in the human body. The results of analyses of twenty-five autopsies from one city will be reported.

High-Energy Symposium

(R. T. LAGEMANN AND W. G. POLLARD presiding)

Invited Papers

I1. A Survey of Fixed-Frequency High-Energy Accelerators. T. A. WELTON, *Oak Ridge National Laboratory.* (30 min.)

I2. A Bev High-Current Accelerator. R. S. LIVINGSTON, *Oak Ridge National Laboratory.* (30 min.)

I3. Recent Cloud-Chamber Results on *p-p* Scattering at Cosmotron Energies. M. M. BLOCK, *Duke University.* (30 min.)

I4. Cooperative Research in Physics between Oak Ridge Laboratories and Southern Universities. V. E. PARKER, *Louisiana State University.* (30 min.)

I5. The MURA High-Energy Accelerator. D. W. KERST, *University of Illinois.* (30 min.)

(ARTHUR E. RUARK presiding)

Twenty-Second Anniversary Dinner

Welcome: President CHARLES S. JOHNSON, *Fisk University.*

Address: Today's Views of Benjamin Franklin's Physics. ARTHUR H. COMPTON, *Washington University.*

Theoretical Nuclear Physics

(INGRAM BLOCH presiding)

L1. A Semiclassical Model for Elastic Nitrogen-Nitrogen Scattering. A. ZUCKER AND H. L. REYNOLDS,* *Oak Ridge National Laboratory.*—The differential cross section for the elastic scattering of nitrogen by nitrogen has been measured at 15.0, 17.7, 19.2, and 21.7 Mev. A strong absorption model proposed by Blair[1] was adapted to the problem of scattering of identical particles. The assumption is made that if the potential barrier of the lth wave allows the nuclei to touch or overlap, the wave will be absorbed completely while the waves with l values corresponding to the nuclei not touching are left undisturbed and have the phase characteristics of pure Coulomb scattering. A good fit was obtained at 21.7 Mev if the cut-off l value was taken as $l=6$, as obtained from the potential outside the nucleus. The fit is quite sensitive to the nuclear radius and in this case $r=4.0\pm0.2\times10^{-13}$ cm. This radius is in agreement with the value determined from fast neutron scattering. In the relation $r=r_0\times A^{1/3}$, $r_0=1.66\times10^{-13}$ cm; a much larger value than that obtained in recent electromagnetic measurements.

* Now at University of California Radiation Laboratory, Livermore, California.

[1] J. S. Blair, Phys. Rev. **95**, 1218 (1954).

L2. Energy Dependence of Stripping Reaction Angular Distributions. M. M. GORDON AND H. A. MOORE, *University of Florida.*—A simple method has been devised for testing whether the angular distributions obtained in a (d,p) reaction at different energies are at all consistent with the simple (Born approximation) stripping theory. For it may be shown that $(k_d/k_p)\sigma(\theta)$ plotted *vs* $|\mathbf{k}_p-\frac{1}{2}\mathbf{k}_d|$ will yield the exact same curve at all energies where the theory is valid. This method of testing the theory, based on inner consistency, is valid for all the known forms of the simple theory, and is furthermore independent of the details of the reaction. A further conclusion from this analysis is that an excitation function for a (d,p) reaction measured over a wide energy range at a given angle is entirely equivalent to an angular distribution curve obtained at one energy wherever the theory is valid. This method of analysis is being applied to the $O^{16}(d,p)$ and $C^{12}(d,p)$ reactions, for which good data are not available on both angular distributions and excitation functions. Preliminary results indicate that the simple theory is applicable only in a very qualitative sense, and even then only if the data are averaged over resonances.

L3. Proton Potential Anomaly.* ALEX E. S. GREEN, *The Florida State University.*—The attractive proton potential anomaly which must be introduced to account for proton binding energies is studied in detail. An experimental measure of the magnitude of the anomaly is established with the aid of a simple perturbation method in which the classical Coulomb effect serves as a basis for comparison. It is found that the anomaly can be characterized successfully in a number of ways: (a) by distorting the Coulomb energy inside the nucleus, (b) by assuming an anomalous potential proportional to the neutron excess density, and (c) by assuming the presence of a Heisenberg force. In addition, it is possible to approximately deduce the anomaly by assuming that the nuclear potential is velocity dependent. A rather high degree of dependence is required, however, corresponding to a reduced mass of the order of 0.25. It does not appear that the simple assumption of an extra well depth for protons will yield satisfactory proton binding energies. A number of explanations of the anomaly are considered. These include (a) the failure of Koopman's theorem, (b) the assumption that the IPM potential incorporates many-body effects, (c) the breakdown of electrostatic laws, (d) the effect of the exclusion principle, (e) the presence of exchange forces, (f) the presence of velocity dependent interactions, and (g) the charge dependence of nuclear forces. With the proton potential anomaly, one would expect that the derived IPM mass surface would yield sufficient symmetry energy.

* This investigation was supported by a grant from the U. S. Atomic Energy Commission.

L4. Nuclear Wave Functions Based upon Harmonic Oscillator and Diffuse Boundary Potentials.* P. C. SOOD AND A. E. S. GREEN, *The Florida State University.*—The rms radii of nuclear orbitals have been calculated for realistic diffuse boundary potentials which have been adjusted to be in accord with low-energy neutron scattering and neutron binding energy data. On the basis of these radii the harmonic oscillator parameter $a=(m\omega/h)^{1/2}$ have been calculated for orbitals in nuclei with mass numbers 50, 100, 150, 200, and 250. Contrary to expectations based upon the harmonic oscillator potential, the values of a for any one mass number vary from state to state. However, it is found that those states which are just being filled have values of a which are fairly consistent. Accordingly, it is possible to assign an a to each nucleus which works rather well for these levels and which varies monotonically with mass numbers. The foregoing procedure represents an improvement over the previous technique of equating the calculated orbital radius to the usual expression for nuclear radius. Having obtained a harmonic oscillator parameter for any mass number one might now make a detailed comparison of the harmonic oscillator wave functions based upon this parameter and the wave functions based upon realistic diffuse boundary potentials. The results of this study will be presented.

* Supported by a grant from the Research Corporation.

L5. Significance of the Possible Existence of Σ Nuclei. W. G. HOLLADAY, *Vanderbilt University* (introduced by E. A. Jones).—Since the selection rules of Nishijima and Gell-Mann permit the fast reactions $\Sigma^-+P\rightarrow\Lambda^0+N$ and $\Sigma^++N\rightarrow\Lambda^0+P$, it is expected that Σ particles will not be found to be a constituent of most nuclei. However, Σ^- particles may be bound in nuclei containing just neutrons and Σ^+ in nuclei containing just protons, since the above reactions are not permitted by the law of conservation of electric charge. Very probably the operation of the Pauli principle for the nucleons will limit such nuclei to the following: (Σ^-,N), (Σ^-,N,N), (Σ^+,P), and (Σ^+,P,P). Whether such nuclei actually exist depends on the forces that act between Σ particles and nucleons. If such nuclei do exist, then, it seems very likely that such forces are mediated at least partially by the pion field. This follows from the fact that heavy meson forces seem to be inadequate to bind the Λ^0 in such nuclei according to the best experimental evidence now available. The existence of these Σ nuclei would then provide evidence for the conservation of "mesic charge," i.e., conservation of the sources of the pion field. It has been suggested by Wigner that such a conservation law may be responsible for the conservation of heavy particles. Furthermore the existence or nonexistence of such nuclei can be enlightening in connection with the strong repulsive core in the nucleon-nucleon potential, since the core may be attractive for Σ particles and nucleons.

L6. Relativistic Dipole Sum Rule.* J. S. LEVINGER, *Louisiana State University.*—The sum of the electric dipole nonretarded oscillator strength can be written[1] as $\Sigma_n f_{on}=m(\partial^2 H/\partial p_z^2)_{00}$, where we evaluate the ground-state expectation value of the second partial derivative of the Hamiltonian H. The Schrodinger Hamiltonian gives the well-known Thomas-Reiche-Kuhn sum rule of unity. If we use the Pauli Hamiltonian[2] as a $(v/c)^2$ approximation to the Dirac Hamiltonian, we obtain a summed oscillator strength of $1-(5/6)(Z/137)^2$ for an electron in a Coulomb field. We shall present numerical values for the retardation correction, and for the correction for electric quadrupole transitions. We shall compare our numerical result with the value 0.87 found for the summed oscillator strength for all multipoles with retardation, for a K electron of lead.[3]

* Supported by the National Science Foundation.

[1] R. G. Sachs and N. Austern, Phys. Rev. **81**, 705 (1951). Eq. (34).

[2] See for example, L. I. Schiff, *Quantum Mechanics* (McGraw-Hill Book Company, Inc., New York, 1949), Eq. (44.8).

[3] J. S. Levinger and M. L. Rustgi, Bull. Am. Phys. Soc. Ser II, 1, 84 (1956).

Invited Papers

L7. Systematics of Properties of Medium Weight Nuclei. KATHARINE WAY, *National Research Council.* (30 min.)

L8. Nucleon Contributions to Nuclear Moments of Inertia. D. R. INGLIS, *Argonne National Laboratory.* (30 min.)

Minutes of the Spring Meeting of The Ohio Section of The American Physical Society Held at Wittenberg College, Springfield, Ohio, April 20 and 21, 1956

THE regular spring meeting of the Ohio Section of the American Physical Society was held at Wittenberg College, Springfield, Ohio, on Friday and Saturday, April 20 and 21, 1956. This meeting was held jointly with the physics-astronomy section of The Ohio Academy of Science, which has been the custom for several years.

Friday afternoon, April 20 was devoted to invited papers relating to the theme, "Education for More and Better Physicists." The speakers were as follows: Dr. M. H. Trytten, Director of Office of Scientific Personnel, Washington, D. C. who spoke on, "The Need for Scientists"; Dr. Mark G. Foster, The Cornell Aeronautical Laboratory, Buffalo, New York, whose subject was, "What Kind of Education for the Industrial Technical Laboratory"; Dr. Gerald A. Rosselot, Bendix Aviation Corporation, Birmingham, Michigan, "Industrial Research as a Career for a Physicist"; Dr. Leonard O. Olsen, Case Institute of Technology, who pointed out highlights from "The Report from the Joint NRC-AIP Conference on Production of Physicists"; and Mr. Merle E. Flamm, Clyde High School, Clyde, Ohio, who spoke on "The High School Teacher in Relation to the Problem."

The Saturday morning session was given over to the program of contributed papers, of which the following five titles do not have abstracts: **The Clustering of Meteors,** Lloyd R. Wylie, *Wittenberg College,* and Horace Castello, *Wright Air Development Center, Wright-Patterson Air Force Base, Ohio;* **Science in High Schools in 1954–1955,** W. M. Pierce, *Ohio University, Athens, Ohio;* **Basic Ideas of Alternate Focusing Gradient in High-Energy Accelerators,** H. J. Hausman, *The Ohio State University, Columbus, Ohio;* **Plans of Midwest University Research Association,** Carl E. Nielsen, *The Ohio State University, Columbus, Ohio;* and, **Radioactivity Fallout in Columbus,** Alma Van Horne and M. L. Pool, *The Ohio State University, Columbus, Ohio.*

This being the annual business meeting of the Ohio Section, the following officers were chosen for the year 1956–1957: Chairman, Dr. Edward S. Foster, Jr., University of Toledo, Toledo, Ohio; Vice-Chairman, Wendell R. Koch, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; and Secretary-Treasurer, Leon E. Smith, Denison University, Granville, Ohio.

Abstracts of the twelve contributed papers follow.

Leon E. Smith, *Secretary*
Ohio Section American Physical Society
Denison University
Granville, Ohio

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1. Planimeter Theory Applied to a General Physics Experiment. Ray L. Edwards, *Miami University.*—Theory is derived for the absolute measurement of area using a planimeter from which all graduations on the sliding arm are removed or ignored. Interest of the student is aroused by having him measure the area in square miles of the United States on a conic projection from which the scale of miles is deleted. The parallels of latitude, of course remain.

2. Analog Computer in Classroom and Laboratory. J. W. McGrath, *Kent State University.*—Since the electronic analog computer is important in technology and scientific research, its capabilities and operation should be familiar to most physicists. An inexpensive computer has been built and used in the physics classrooms and laboratories at Kent State University. A description of the computer and its employment in teaching and in academic research is given. The computer will be demonstrated after the meeting.

3. Plausibility of the Electron-Spin Hypothesis. W. H. Davis, *Marietta College.*—In most treatments of atomic spectra the existence of electron spin, its value and its two possible orientations are first stated as assumptions. Then such phenomena as Zeeman effect, fine structure, etc., are explained using these assumptions. The author will describe his attempts at presenting the empirical evidence in such a manner as to suggest the postulates in as direct a manner as possible.

4. A Simple Electromagnet Suitable for Nuclear Magnetic Resonance Experiments. Thomas S. Smith, *The Ohio University.*—The construction details and performance data are given for an electromagnet which produces a field of 4000 gauss in a 2-in. gap using only 200 w. The field is homogeneous to 1 part in 15 000 over a 1.4-cc volume, and stable to within 0.5 gauss in 2000 gauss over a period of 3 hr.

5. Standing and Traveling Wave Demonstration. W. J. Price and J. T. Miskimen, *U. S. Air Force Technological Institute, Wright-Patterson Air Force Base.*—Demonstration equipment consisting of the Cenco universal wave apparatus and a jet-operated driving system is described. With this apparatus it is possible to demonstrate with ease various traveling and standing wave phenomena which are not convenient with a mechanical driving system. The system is driven by expelling air from the small jets attached to the lowest vibrator arm. Two sets of jets are employed, one with a constant air flow and the other with its air flow varied sinusoidally around the constant value. In this fashion a driving torque of variable amplitude and frequency is achieved without restricting the motion of the driven end.

6. Vapor Pressure of Cobaltous Chloride. Carl A. Alexander and Thomas S. Smith, *The Ohio University.*—The vapor pressure of cobaltous chloride has been measured using the transpiration method in the range from 660°C to 1000°C. An attempt has been made to evaluate the effects of flow rate and diffusion on the results. Vapor-solid and vapor-liquid equilibrium curves are given with a melting point indicated at 723±5°C.

7. Principle of Equivalence. A. B. STEWART, *Antioch College.*—The precise proportionality of the inertial and gravitational properties of all matter is one of the basic assumptions of general relativity. It is of interest, therefore, to review the accuracy with which this proportionality has been established by direct experiment. Newton, Bessel, and Thomson have each contributed to the experimental test of the principle of equivalence, but the work of Eötvös,[1,2] which established the proportionality to 5 parts in a billion, is by far the most precise. Other possible ways of testing this principle, none of which seem promising, will be discussed along with the method of Eötvös.

[1] R. V. Eötvös, Math. u. naturw. Ber. Ungarn **8**, 65 (1889–1890).
[2] Eötvös, Pekár, and Fekete, Ann. Physik **68** (1922).

8. Ionization in the Oscillating Glow Discharge.* STEVEN GROVES, G. E. OWEN, AND A. B. STEWART, *Antioch College.*—The plasma potential and electron concentration have been measured as functions of time and position in the positive column of an argon glow discharge with moving striations at 6 mm Hg pressure using a plane circular probe 0.25 mm in diameter that could be saturated in the electron collecting region. An expression relating the rate of ionization to the plasma potential and the charge concentration has been obtained using mobility and diffusion relations together with the assumption of equal positive and negative charge concentrations. The space and time dependence of the rate of ionization calculated from the probe data using this expression is found to agree closely with the variations in the relative light intensity measured with a moveable photomultiplier tube.

* Supported by the National Science Foundation.

9. Beta Spectrum of Promethium-147 Using a Diffusion Cloud Chamber.* A. A. SILVIDI, *Kent State University.*—Using a diffusion-type cloud chamber built at this laboratory, 639 pictures were taken of a Pm^{147} high-purity (greater than 99%) sample. There were 526 pictures which had 854 measurable beta tracks. Of these 556 were definitely from the sample while the remaining 298 were due to the background radiation. A beta spectrum was plotted from which, using standard methods,[1] a Fermi-Kurie plot was constructed. The end-point energy from this plot gave 231 kev as compared with the accepted value of 223 kev for a 3.5% error. The spectrum agrees very well with that obtained by Pohm and workers[2] who used a spectrometer of the intermediate-image type.

* Supported by the National Science Foundation.
[1] "Table for analysis of beta spectra," National Bureau of Standards, Applied Mathematics Series 13.
[2] Pohm, Waddell, Powers, and Jensen, Phys Rev. **97**, 432 (1955).

10. Diffusion of Ra^{224} and Em^{220} in Nuclear Emulsions. C. A. RANDALL, JR., AND L. H. GALLAHER, *The Ohio University.*—The diffusion coefficients of Ra^{224} and Em^{220} have been calculated from measurements of the "splitting" of thorium α-particle stars in Eastman NTA emulsion. The results do not agree with those reported[1] for the diffusion of thoron in Ilford *C2* emulsions. The observations on Ra^{224} seem to suggest that the diffusion process is not merely simple Brownian motion.

[1] G. G. Eichholz and F. C. Flack, J. Chem. Phys. **19**, 363 (1951).

11. Gamma-Gamma Coincidences of Rhodium Isotopes. KAZUO HISATAKE, JAMES T. JONES,* AND J. D. KURBATOV, *The Ohio State University.*—Coincidences of gamma rays[1] emitted by rhodium isotopes of $T(\frac{1}{2})$ greater than ten days have been studied with a scintillation spectrometer. The coincidence results together with half-life determination allows separation of the gamma rays into three groups[2]: (1) Gamma rays of 88 and 348 kev have a half-life 16 ± 1 days and are in coincidence with each other. (2) The 1100-, 630-, and 475-kev gamma rays were found to have a half-life 210 ± 10 days and are in coincidence with each other; they result from the decay of Rh^{102}. (3) The 125- and 190-kev gamma rays do not as previously reported[1] belong to Rh^{102}, but to a species of $T(\frac{1}{2})$ approximated to be more than 3 years; they are in coincidence with each other. These results, together with gamma rays reported from Coulomb excitation of enriched ruthenium[3] suggest possible isotope assignment of (1) to Rh^{99} and (3) to Rh^{101}.

* Major, U. S. Air Force, at present on tour of duty at The Ohio State University.
[1] Kurbatov, Hisatake, and Jones, Bull. Am. Phys. Soc. Ser. II, 1, 134 (1956).
[2] D. J. Farmer, Phys. Rev. **99**, 659(A) (1955).
[3] G. M. Temmer and N. P. Heydenburg, Phys. Rev. **100**, 961(A) (1955).

12. Demonstration of the Transistor Effect at an Elementary Level. WILLIAM L. LEHMANN, *U. S. Air Force Institute of Technology, Wright-Patterson Air Force Base.*—In describing the operation of a transistor in an undergraduate physics course, it is desirable to present an essentially correct picture while avoiding concepts totally unfamiliar to the student. A simple demonstration which illustrates several phenomena of semiconductor electronics will be presented. A germanium junction diode is etched and then biased to act as a collector. A cat's whisker is then used to make an additional rectifying contact to the *n*-type material and biased to act as an emitter. Holes thus injected into the *n*-type material are swept across the junction giving rise to a collector current. Thus a transistor is created. In explanation, a two-dimensional model of the germanium lattice is introduced and conduction by holes and electrons described. *p*- and *n*-type material are then introduced in the usual manner. The rectifying action of a *p-n* junction is explained and demonstrated, while the rectification of a point contact is simply postulated and shown. The injection of minority carriers is described. Finally, the assembly of the transistor and its external circuit is shown and analyzed to indicate the manner in which voltage amplification results. This demonstration is well suited to laboratory use, giving the student an opportunity to produce hole injection, rectification, and transistor action. It is felt that this is more appropriate to a physics course than experiments which merely treat the transistor as a circuit element.

The American Physical Society

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